A comprehensive summary of current knowledge on the effects of nuclear weapons.

THE EFFECTS OF NUCLEAR WEAPONS

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The main purpose of this new handbook is to describe, within the limitations set by national security, the basic phenomena—blast, shock, and various radiations—and the most recent data concerning the effects associated with explosions of nuclear weapons. The information has been obtained from observations made following the wartime nuclear bombings in Japan and at the tests carried out at the Eniwetok Proving Grounds and the Nevada Test Site, as well as from experiments with conventional high explosives and mathematical calculations.

Intended for use in planning against possible nuclear attack, this volume discusses the general principles of nuclear explosions and their destructive effects. It provides descriptions of nuclear explosions in the air, on the surface, underground, and underwater; the air blast phenomena and effects; structural damage resulting from an air blast; the effects of surface and subsurface bursts; damage from air blast, underground shock, and underwater shock; thermal radiation and its effects; initial nuclear radiation; residual nuclear radiation and fallout; world-wide fallout and long-term residual radiation; effects on personnel; and protective measures against the effects of nuclear explosions. Numerous charts, drawings, and before-and-after photographs add to the completeness of the text. A glossary, bibliography, and index are also included.

Designed to serve a wide audience, the textual material of most of the chapters is presented in two parts: the first consisting of a general treatment of a particular topic in a less technical manner, whereas the second part contains the more technical aspects.

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RECORDING THE VISUAL EFFECT OF AN ATOMIC EXPLOSION: PHOTOGRAPHERS AT WORK AFTER A DEVICE DROPPED FROM AN AIRCRAFT HAD BEEN EXPLODED AT NEVADA.

On March 29 two atomic weapons were exploded at the Nevada Desert testing grounds. The second, a device dropped from a high-flying aircraft, exploded at more than 15,000 ft., with a yellow flash. An atomic cloud appeared to rise quickly from the point of blast, and observers said it was tinted pink with a black inside. Aircraft flew in the area after the tests

The Effects of

Nuclear Weapons

Samuel Glasstone

Editor

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Foreword

This handbook, prepared by the Armed Forces Special Weapons Project of the Department of Defense in coordination with other cognizant government agencies and published by the United States Atomic Energy Commission, is a comprehensive summary of current knowledge on the effects of nuclear weapons. The effects information contained herein is calculated for yields up to 20 megatons and the scaling laws for hypothetically extending the calculations beyond this limit are given. The figure of 20 megatons however is not to be taken as an indication of capabilities or developments.

CHARLES E. WILSON
Secretary of Defense

LEWIS L. STRAUSS
Chairman
Atomic Energy Commission

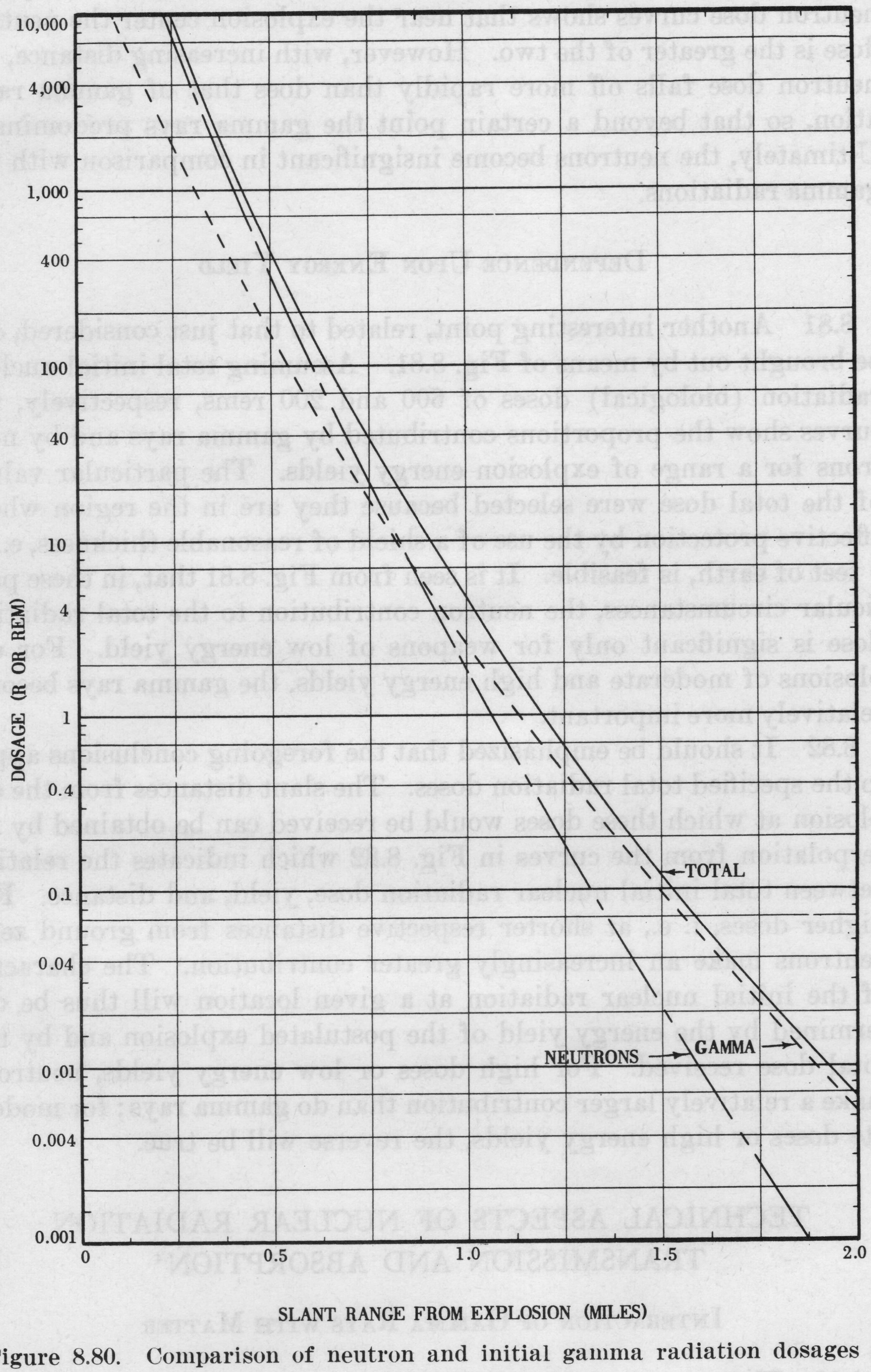


Figure 8.80. Comparison of neutron and initial gamma radiation dosages for a 1-kiloton air burst.

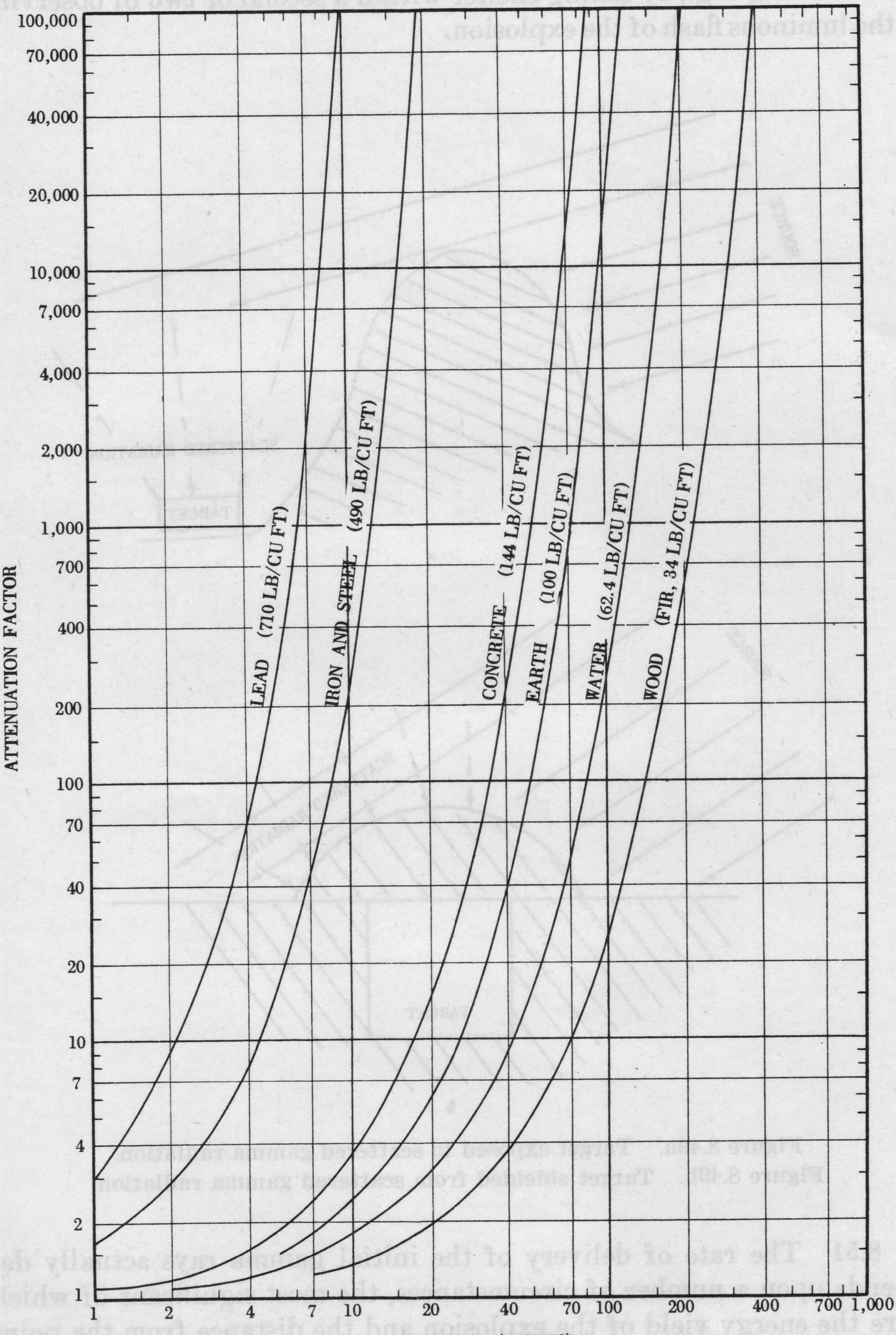


Figure 8.47. Attenuation of initial gamma radiation.

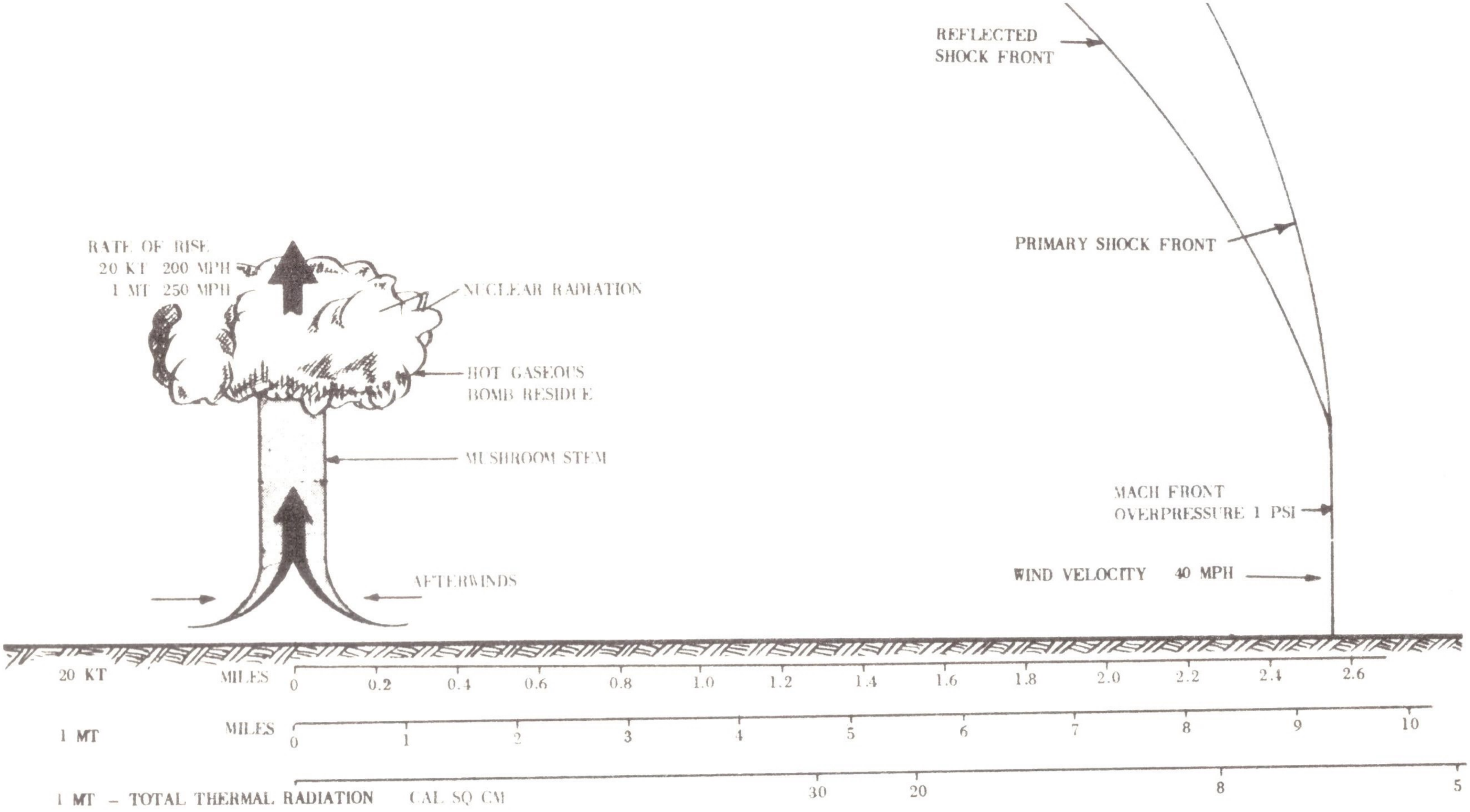


Figure 2.47d. Chronological development of an air burst: 10 seconds after 20-kiloton detonation; 37 seconds after 1-megaton detonation.

Figure 7.70 Partial protection against thermal radiation produced "profile" burns (1.23 miles from ground zero). The cap was sufficient to protect the top of the head against flash burn.

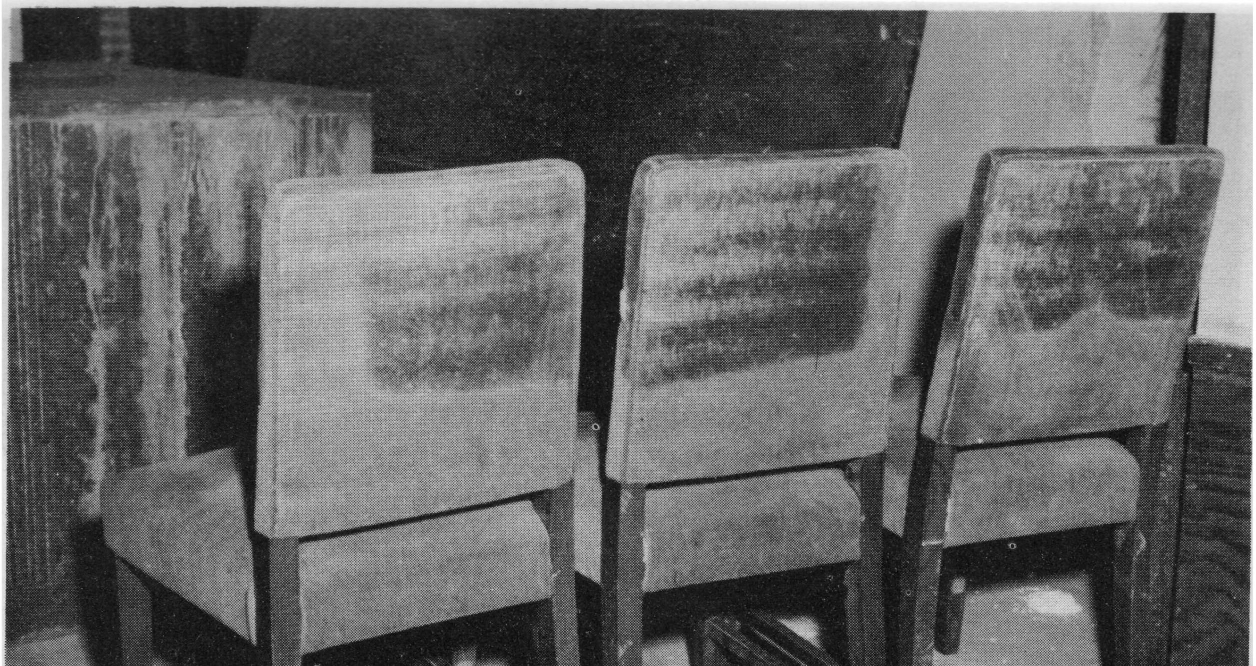


Figure 7.73a. Flash burns on upholstery of chairs exposed to bomb flash at window (1 mile from ground zero at Hiroshima).

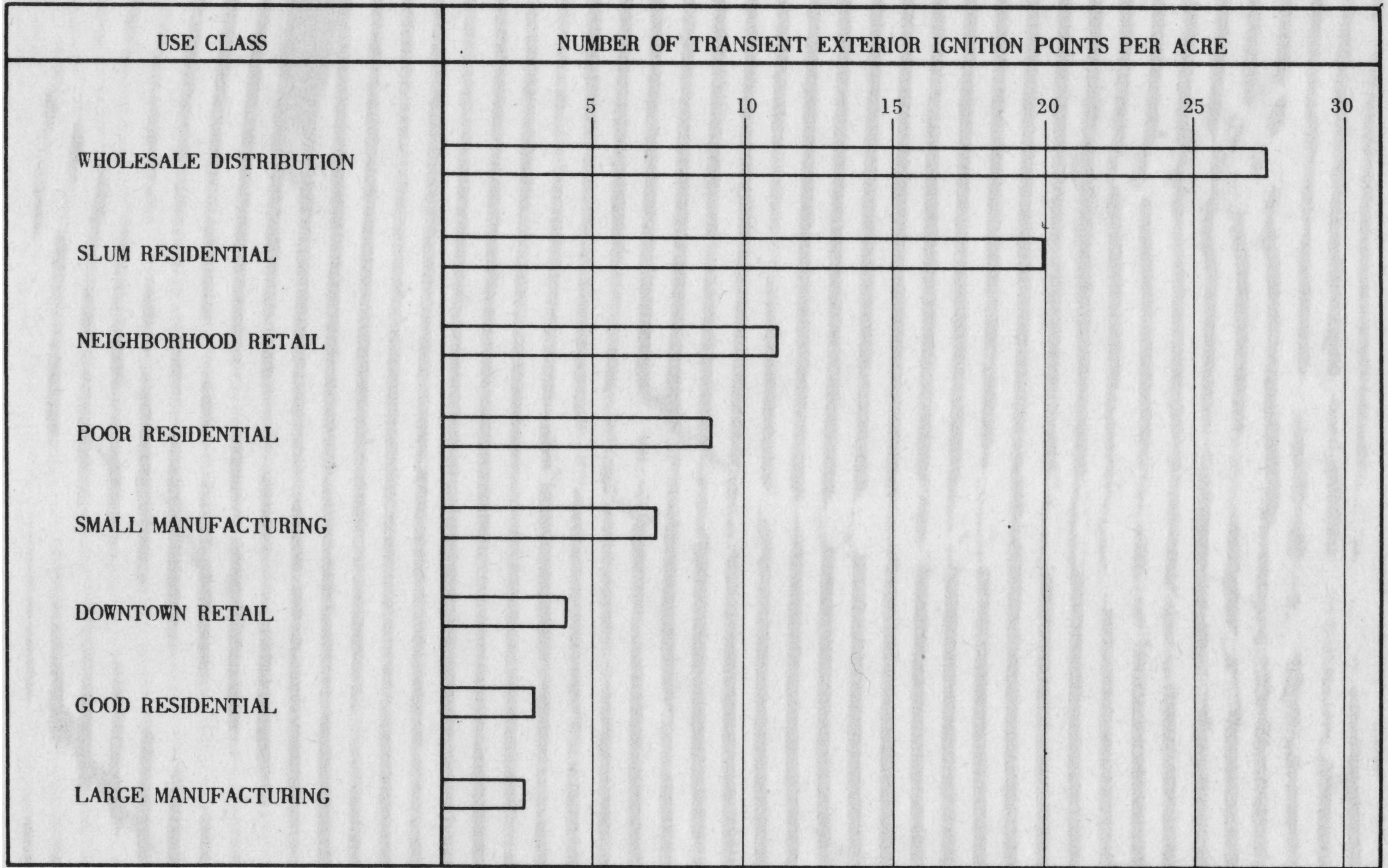


Figure 7.80. Frequency of exterior ignition points for various areas in a city.

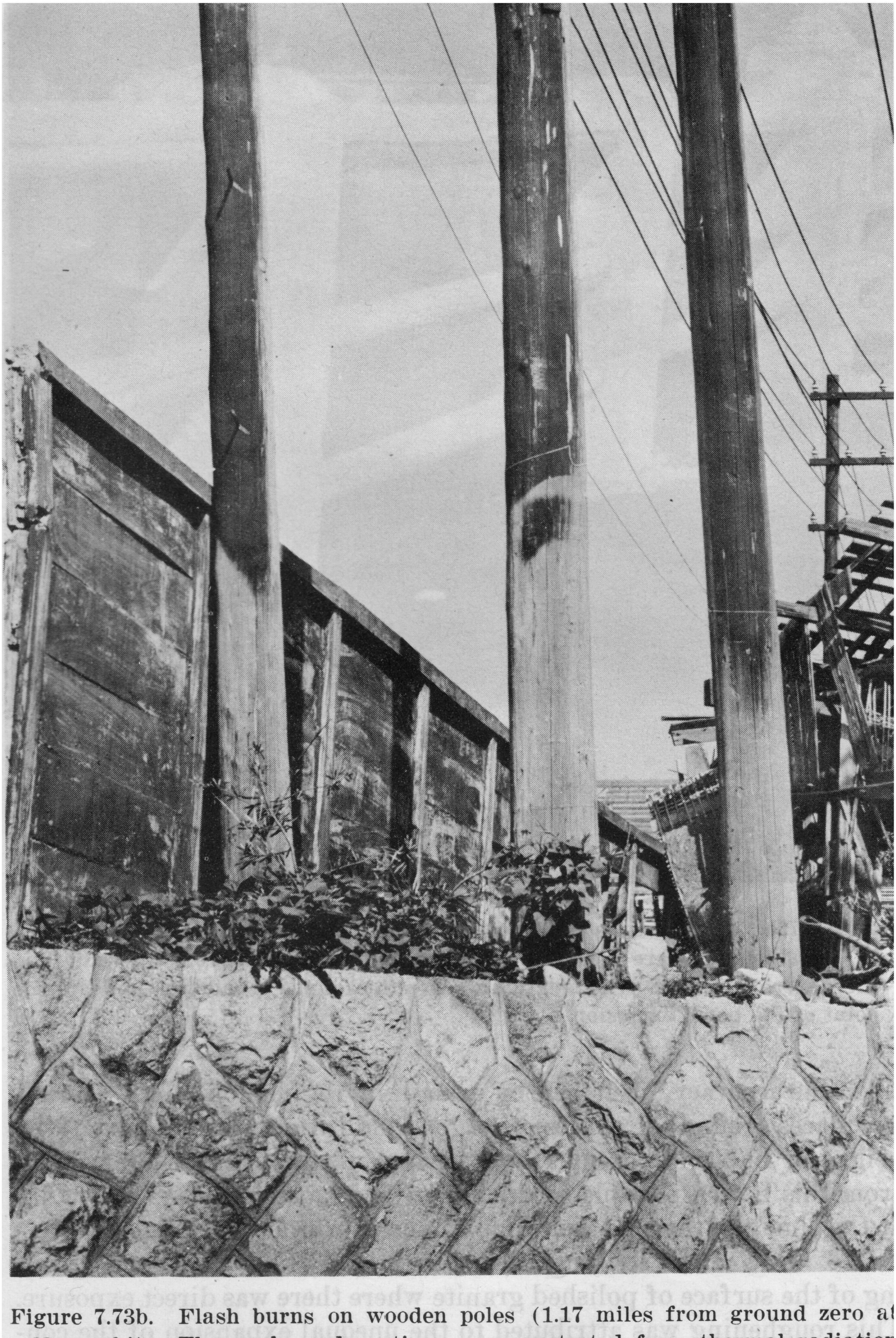


Figure 7.73b. Flash burns on wooden poles (1.17 miles from ground zero at Nagasaki). The uncharred portions were protected from thermal radiation by a fence.

fence, were exposed to 12 calories per square centimeter of thermal radiation. One house, at the left of Fig. 7.82, had weathered siding showing considerable decay, but the yard was free from trash. The next house also had a clean yard and, further, the exterior siding was well maintained and painted. In the third house, at the right of the photograph, the siding, which was poorly maintained, was weathered, and the yard was littered with trash.

7.83. The state of the three houses after the explosion is seen in Fig. 7.83. The third house, at the right, soon burst into flame and was burned to the ground. The first house, on the left, did ignite but it did not burst into flame for 15 minutes. The well maintained house in the center with the clean yard suffered scorching only. It is of interest to recall that the wood of a newly erected white-painted house exposed to about 25 calories per square centimeter was badly charred but did not ignite (Fig. 7.34b).

7.84 The value of fire-resistive furnishing in decreasing the number of ignition points was also demonstrated in the 1953 tests. Two identical, sturdily constructed houses, each having a window 4 feet by 6 feet facing the point of burst, were erected where the thermal radiation exposure was 17 calories per square centimeter. One of the houses contained rayon drapery, cotton rugs, and clothing, and, as was expected, it burst into flame immediately after the explosion and burned completely. In the other house, the draperies were of vinyl plastic, and rugs and clothing were made of wool. Although more ignition occurred, the recovery party, entering an hour after the explosion, was able to extinguish fires.

7.85 There is another point in connection with the initiation of fires by thermal radiation that needs consideration. This is the possibility that the flame resulting from the ignition of a combustible material may be subsequently extinguished by the blast wind. It was thought that there was evidence for such an effect from an observation made in Japan (§ 7.92), but this may have been an exceptional case. The matter has been studied, both in connection with the effects in Japan and at various nuclear tests, and the general conclusion is that the blast wind has no significant effect in extinguishing fires (see § 7.93).

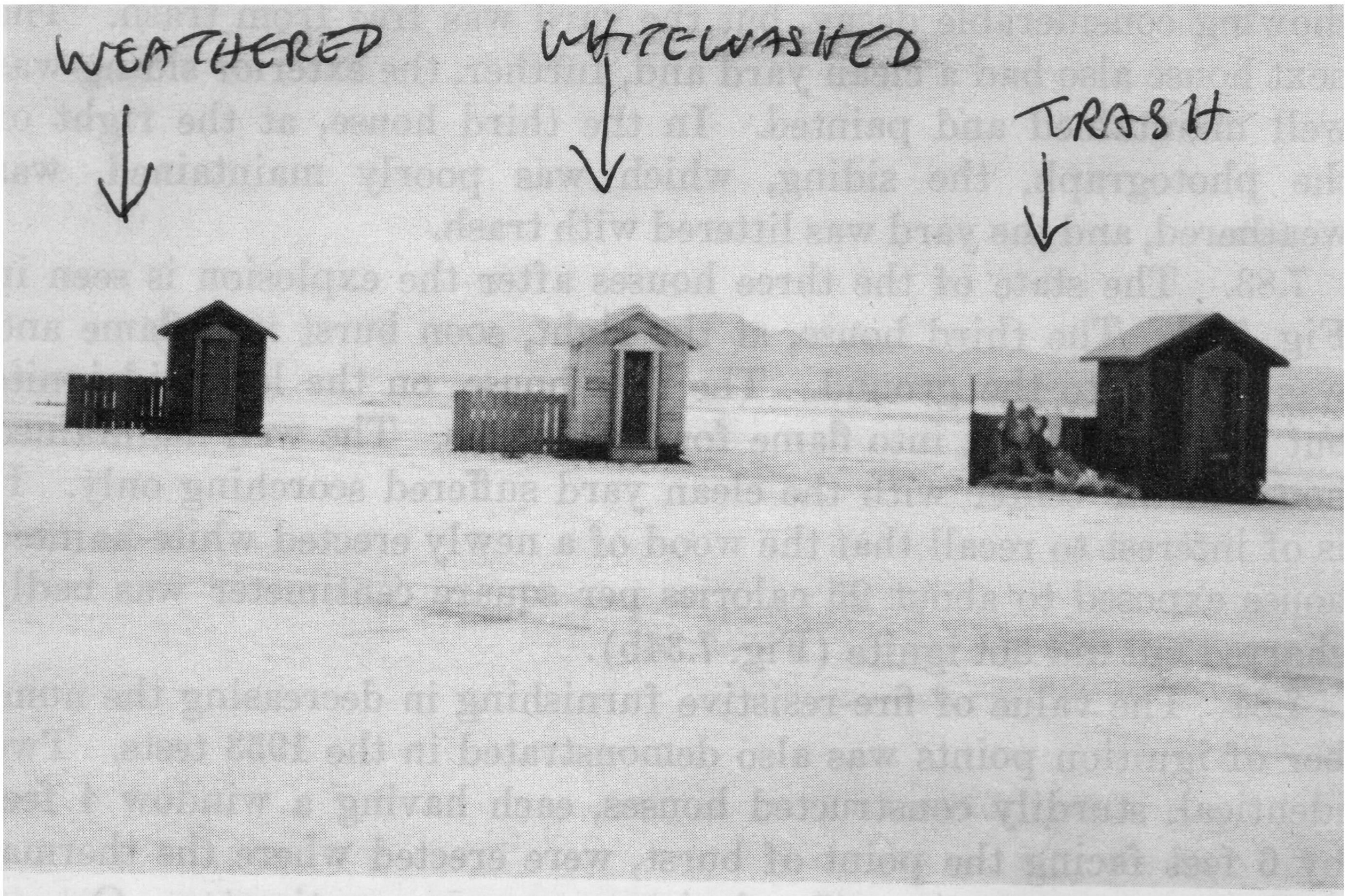


Figure 7.82. Wooden test houses before exposure to a nuclear explosion, Nevada Test Site. ENCORE: 27KT

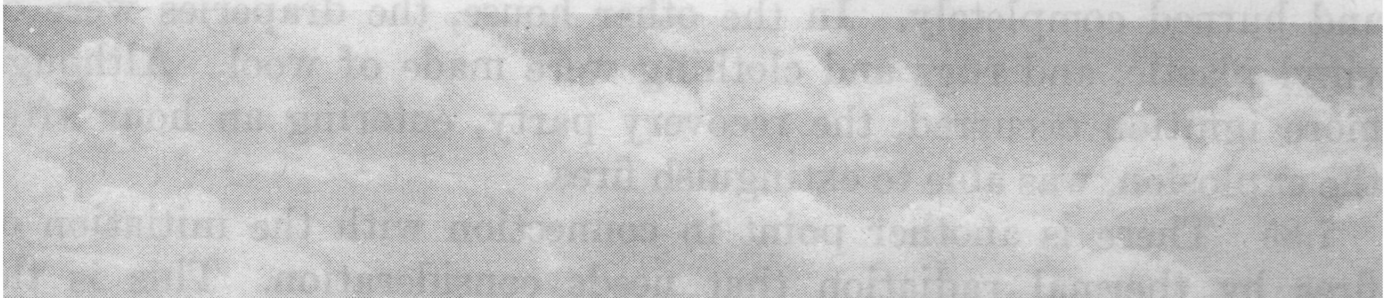


Figure 7.83. Wooden test houses after exposure to the nuclear explosion.

12 Cal/cm^2

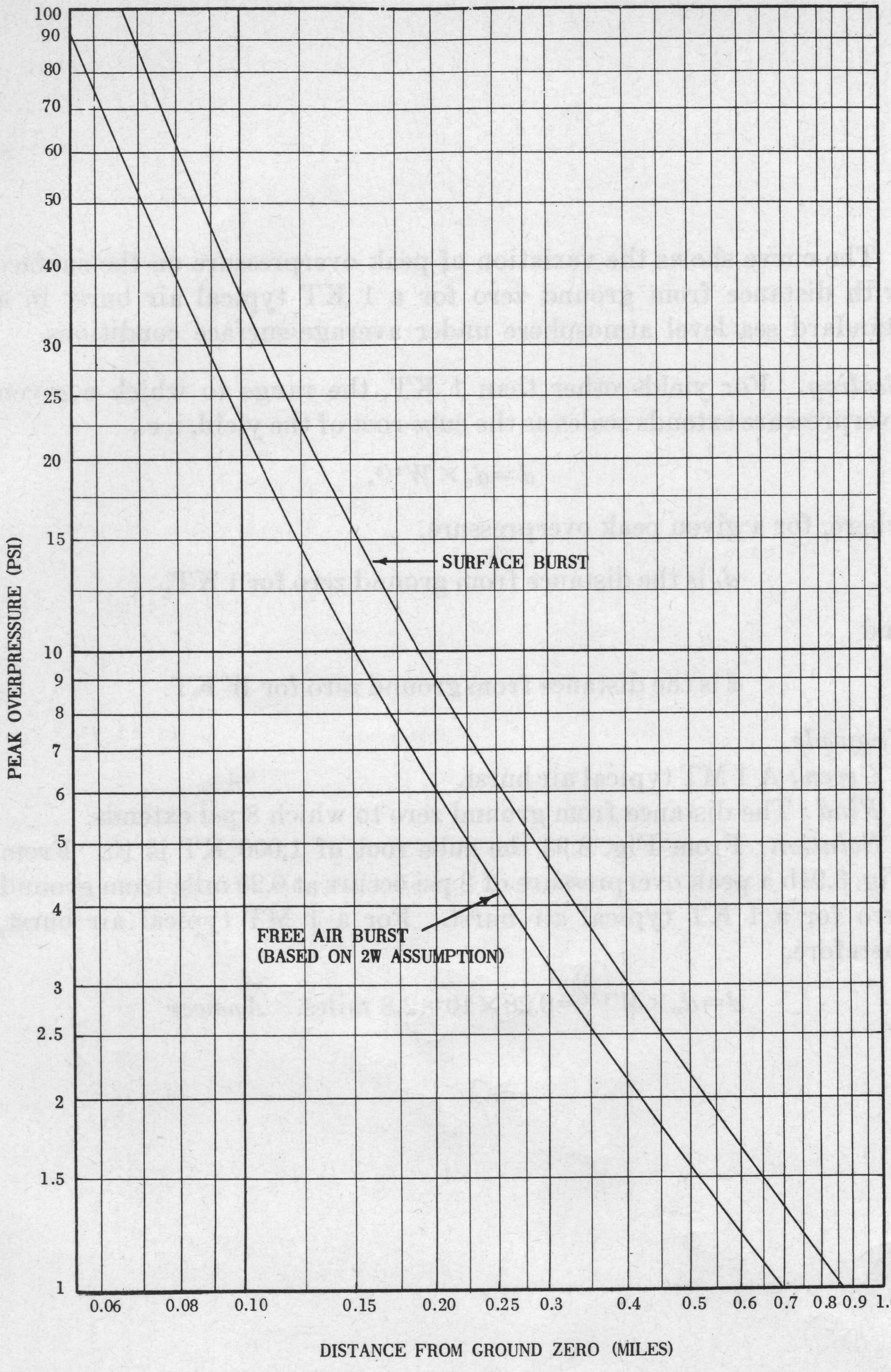


Figure 3.94a. Peak overpressure for a 1-kiloton surface burst and free air burst.

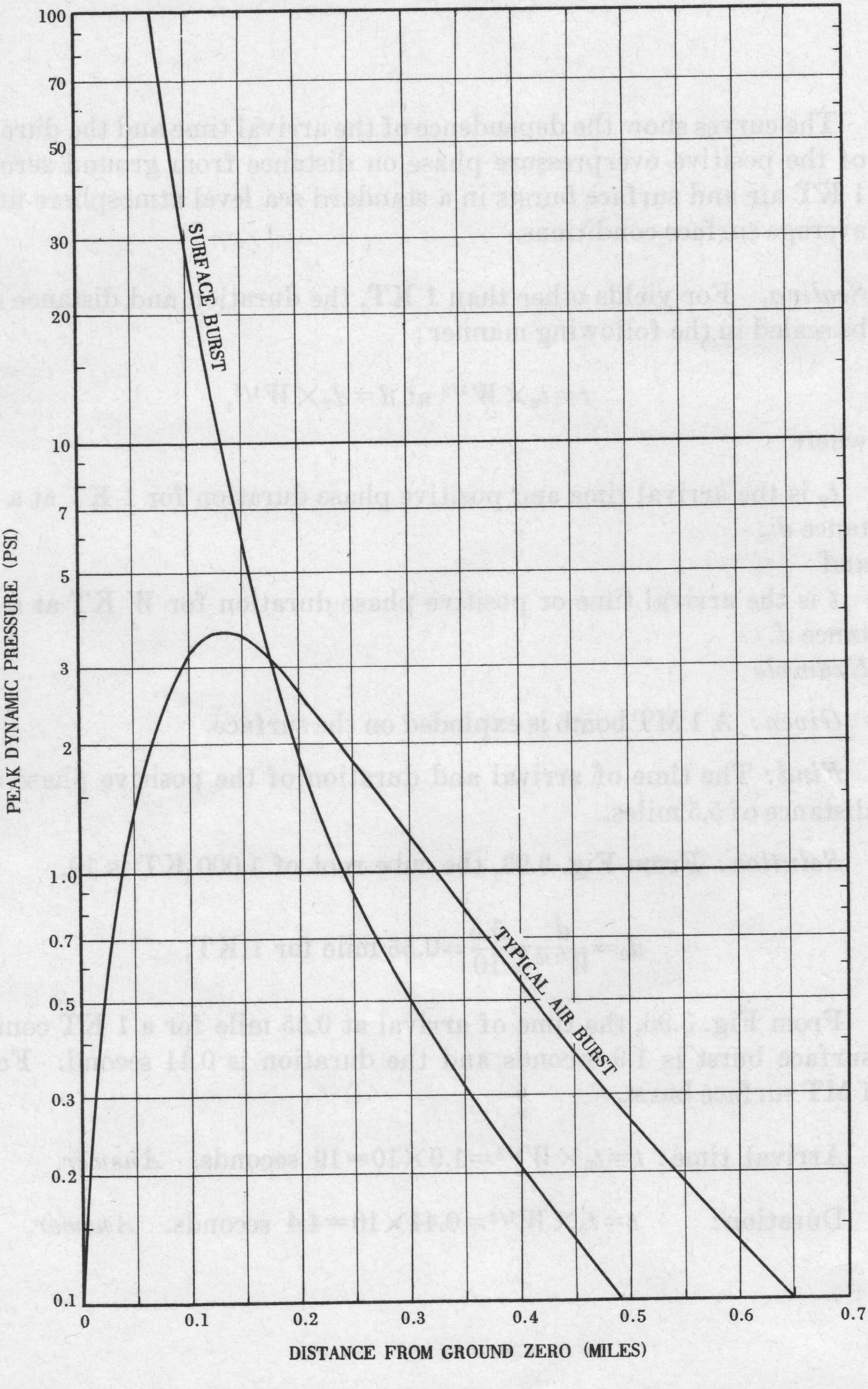


Figure 3.95. Horizontal component of peak dynamic pressure for a 1-kiloton explosion.

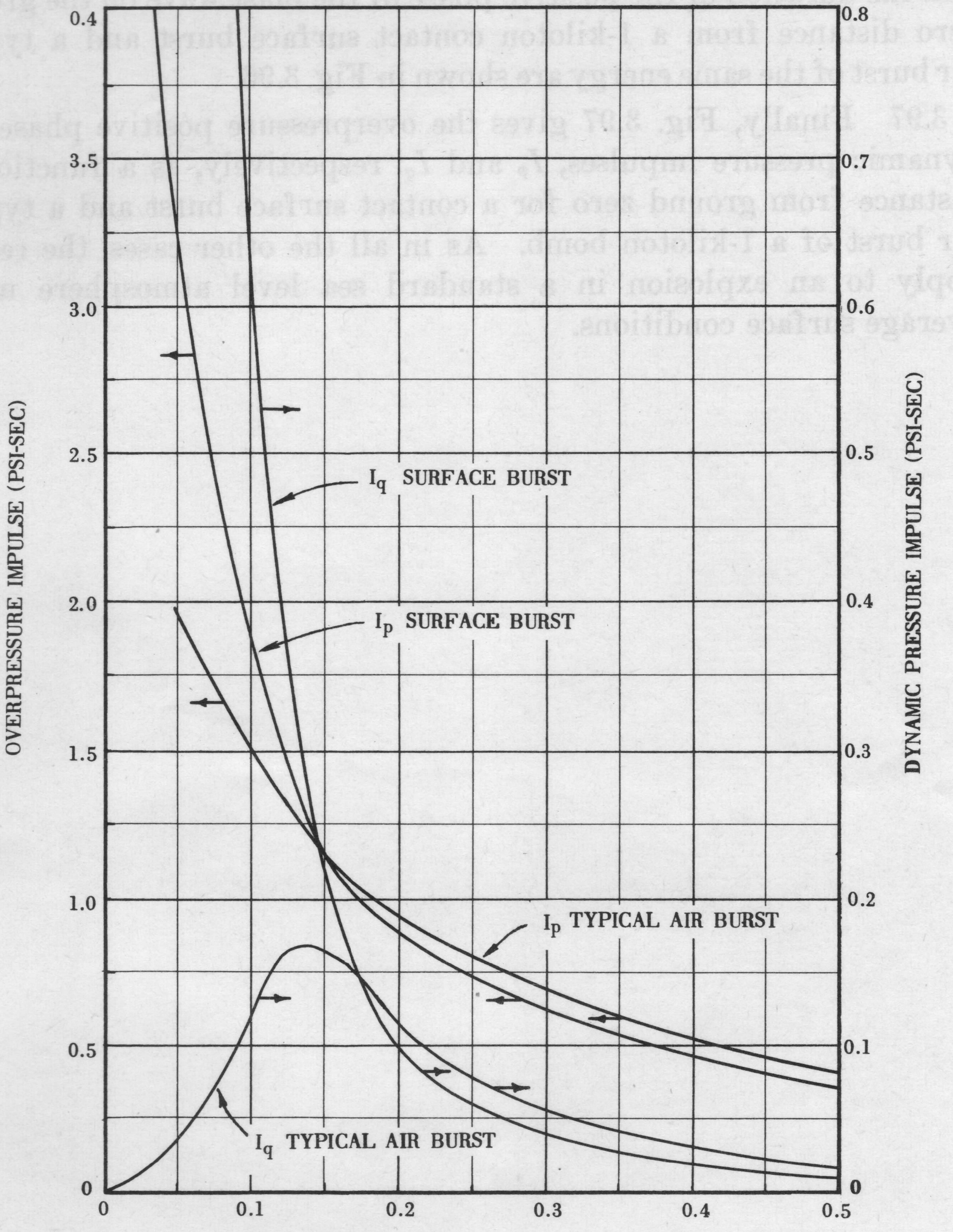
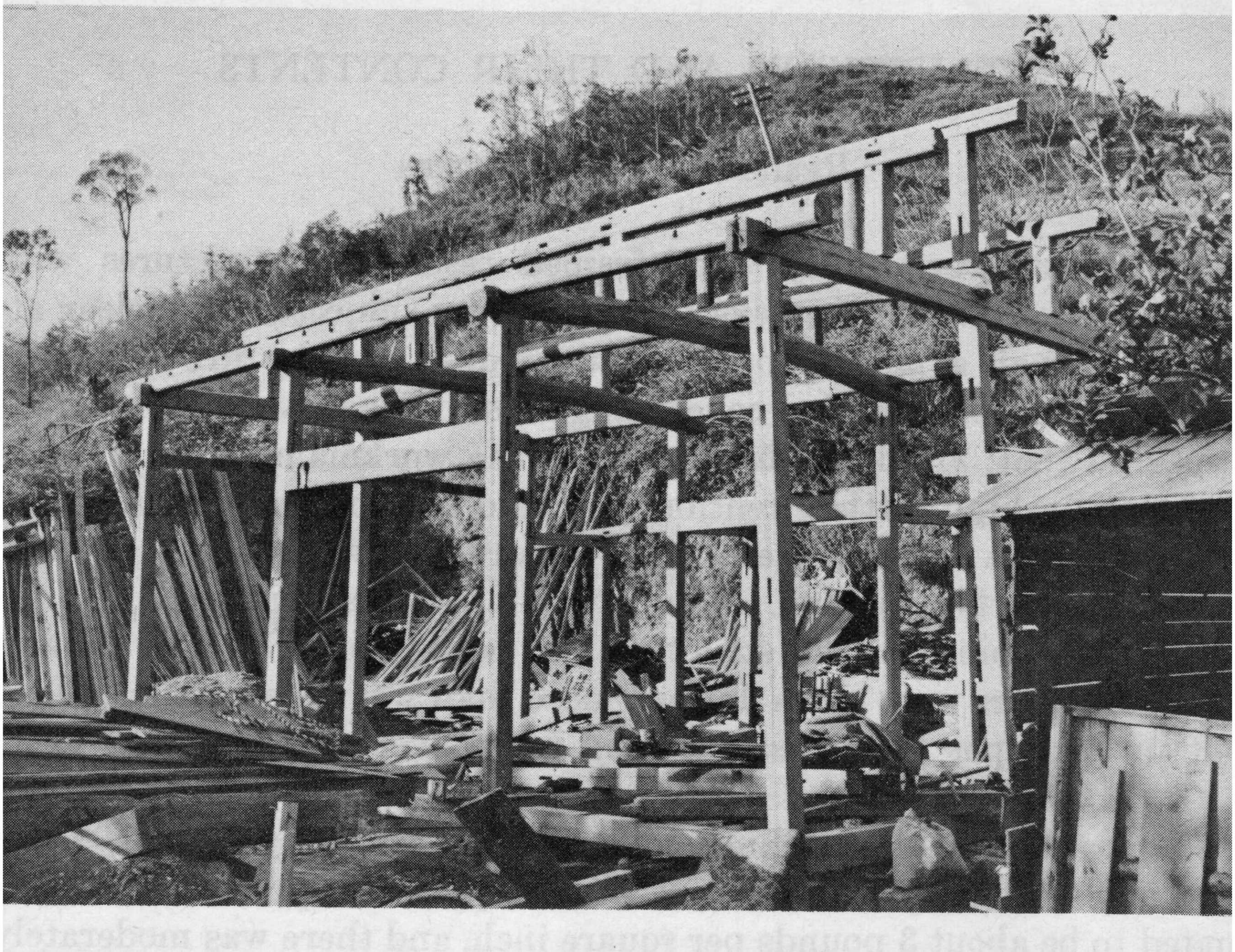


Figure 3.97. Overpressure and dynamic pressure positive phase impulse for a 1-kiloton explosion.



igure 4.8. *Upper photo:* Wood-frame building; 1.0 mile from ground zero at Hiroshima. *Lower photo:* Frame of residence under construction, showing small tenons.

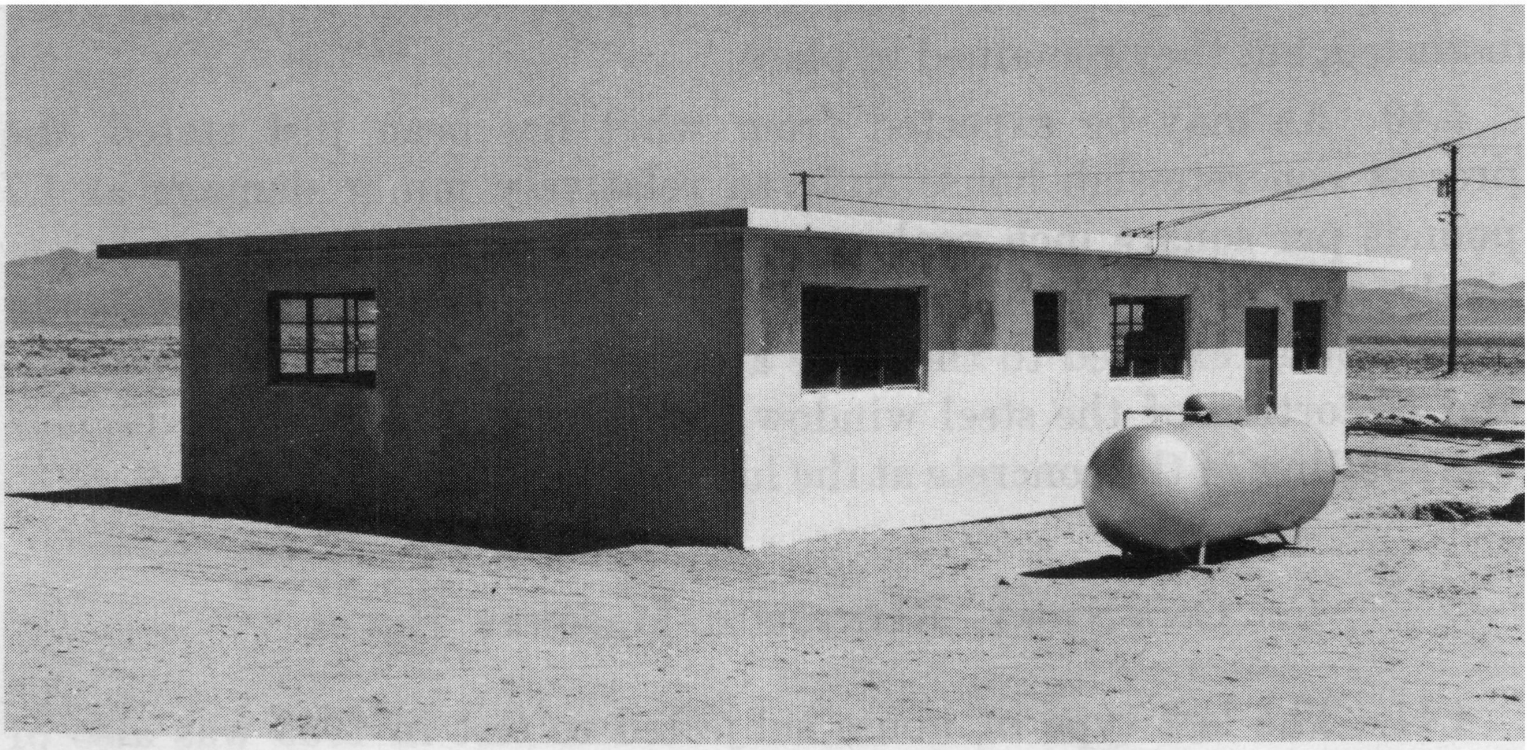


Figure 4.37. Reinforced precast concrete house before a nuclear explosion, Nevada Test Site.

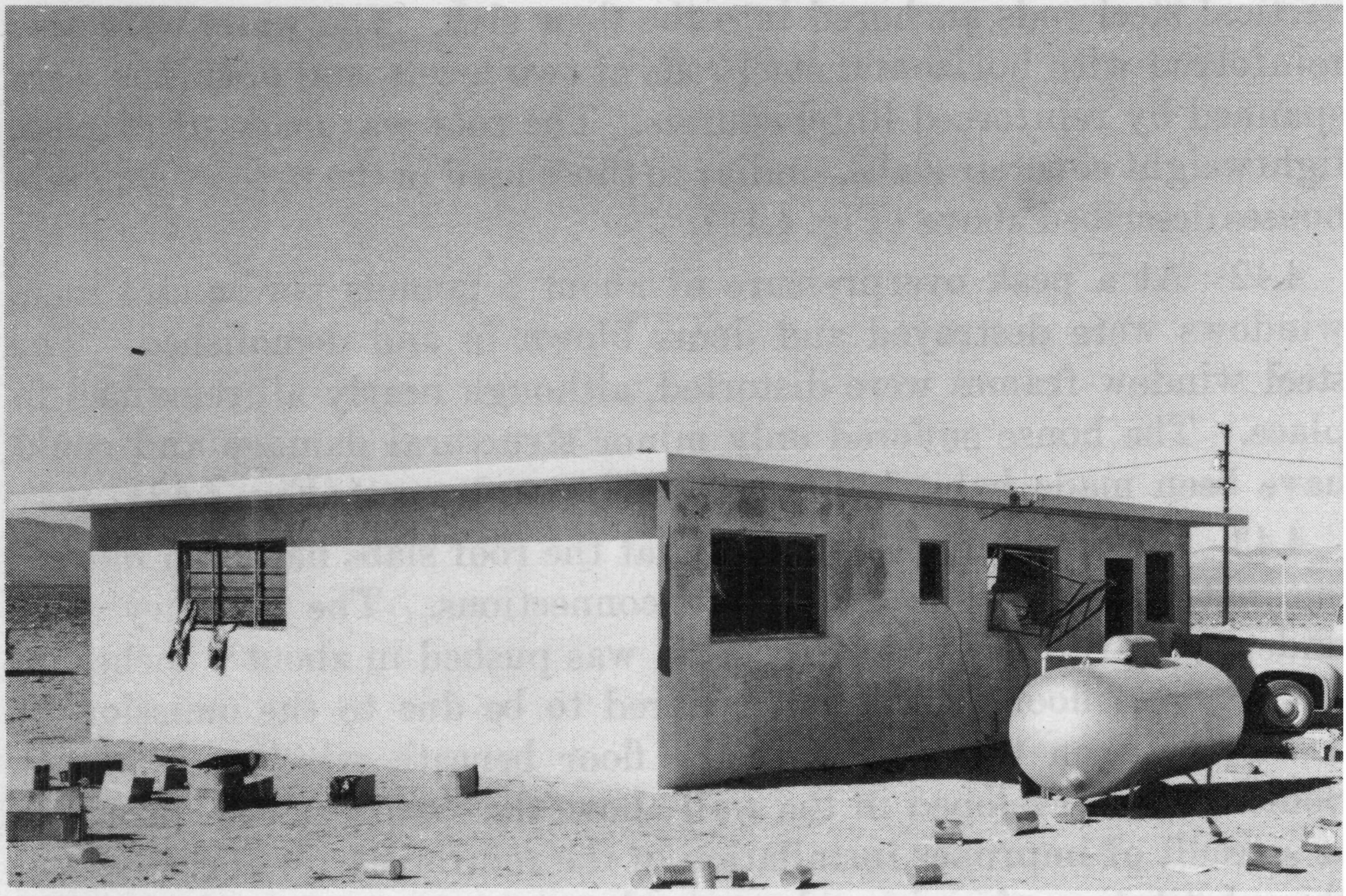


Figure 4.38. Reinforced precast concrete house after the nuclear explosion (5 psi overpressure). The LP-gas tank, sheltered by the house, is essentially undamaged.

igure 4.100b. Aircraft after tail exposed to nuclear explosion (2.4 psi over
pressure)

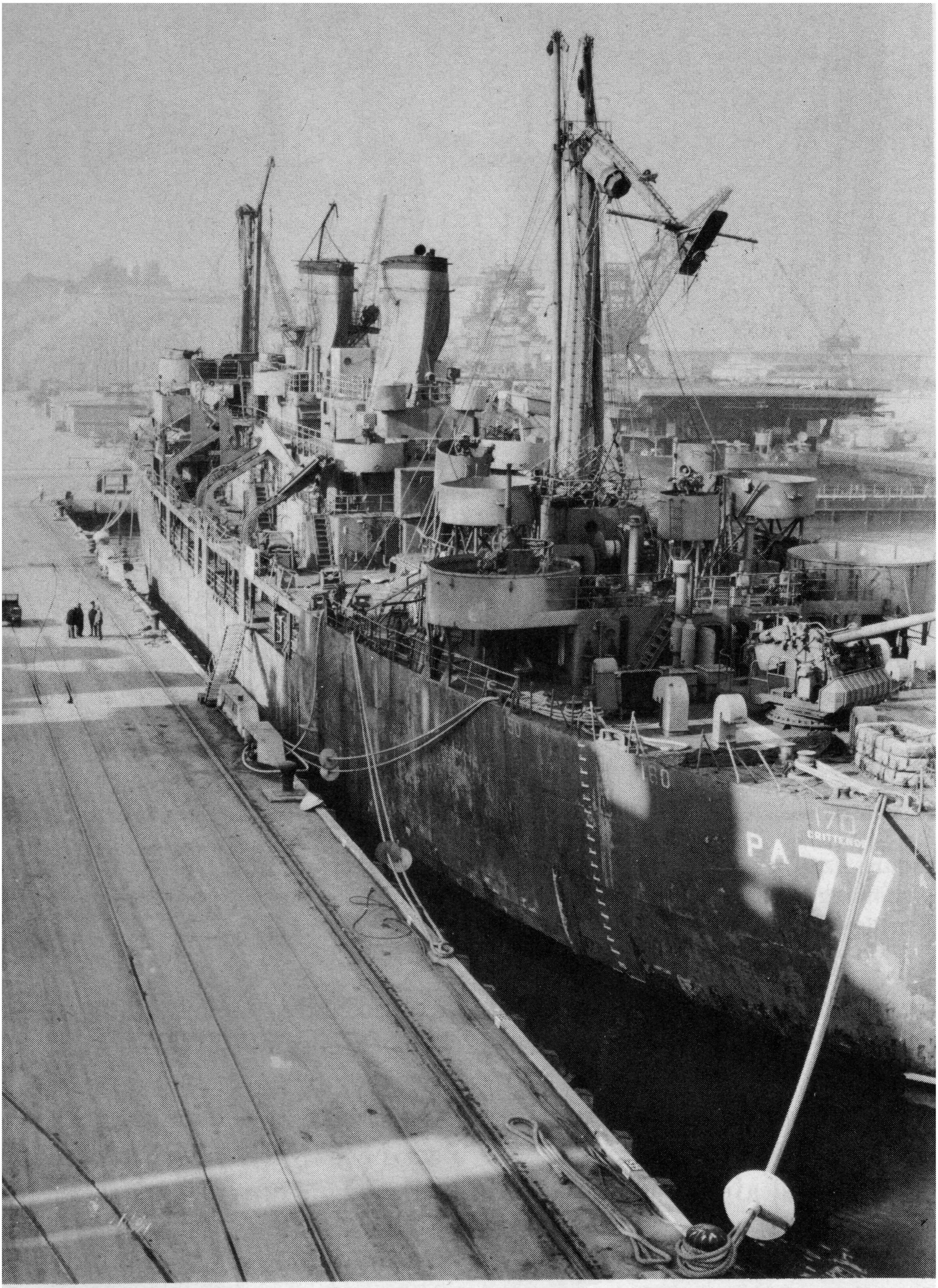


Figure 4.101a. The U. S. S. Crittenden after ABLE test; damage resulting was generally moderate (0.47 mile from surface zero).

Ductility

3.73 The term ductility refers to the ability of a material or structure to absorb energy inelastically without failure; in other words, the greater the ductility, the greater the resistance to failure. Materials which are brittle have poor ductility and fail easily.

3.74 There are two main aspects of ductility to be considered. When a force (or load) is applied to a material so as to deform it, as is the case in a nuclear explosion, for example, the initial deformation is said to be "elastic." Provided it is still in the elastic range, the material will recover its original form when the loading is removed. However, if the "stress" produced by the load is sufficiently great, the material passes into the "plastic" range. In this state the material does not recover completely after removal of the stress, that is to say, the deformation is permanent, but there is no failure. Only when the stress reaches the "ultimate strength" does failure, i. e., breakage, occur.

3.75 Ideally, a structure which is to suffer little damage from blast should have as much elasticity as possible. Unfortunately, structural materials are generally not able to absorb much energy in the elastic range, although many common materials can take up large amounts of energy in the plastic range before they fail. The problem in blast-resistant design, therefore, is to decide how much permanent (plastic) deformation can be accepted before a particular structure is rendered useless. This will, of course, vary with the nature and purpose of the structure. Although deformation to the point of collapse is definitely undesirable, some lesser deformation may not seriously interfere with the continued use of the structure.

3.76 It is evident that ductility is a desirable property of structural materials required to resist blast. Structural steel and steel reinforcement have this property to a considerable extent. They are able to absorb large amounts of energy, e. g., from a blast wave, without failure and thus reduce the chances of collapse of the structure in which they are used. Steel has the further advantage of a higher yield point (or elastic limit) under dynamic than under static loading.

3.77 Although concrete alone is not ductile, when steel and concrete are used together, as in reinforced-concrete structures, the ductile behavior of the steel will usually predominate. The structure will then have considerable ductility and, consequently, resistance to blast. Without reinforcement, masonry walls are completely lacking in ductility and readily suffer brittle failure, as stated above.

TABLE 6.23

DAMAGE CRITERIA FOR TRANSMITTING TOWERS

Damage class	Nature of damage
A and B	Towers demolished or flat on the ground (Fig. 4.109a).
C	Towers partially buckled, but held by guy lines; ineffective for transmission.
D	Guy lines somewhat slack, but tower able to transmit (Fig. 4.109b).

DAMAGE TO FORESTS

6.24 In considering damage to forests, the discussion will refer more specifically to naturally occurring broadleaf and coniferous stands averaging about 175 trees per acre. Because trees are primarily sensitive to drag forces, the zone in which the damage decreases from class A to class D is relatively narrow. In particular, the transition from A to B is difficult to delineate, and so these two types of damage are taken together. The different classifications are described in Table 6.24. Since the effect of air blast on forests is similar to that of strong

Figure 6.24a. Forest stand after a nuclear explosion, B damage (3.8 psi overpressure).

110 KT CASTLE – KOON

Figure 6.24b. Forest stand after a nuclear explosion, C damage (2.4 psi overpressure).

15 MT CASTLE-BRAVO

TABLE 6.24

DAMAGE CRITERIA FOR FORESTS

Damage class	Nature of damage	Equivalent hurricane wind velocity (miles per hour)
A & B	Up to 90 percent of trees blown down; remainder denuded of branches and leaves (Fig. 6.24a). (Area impassable to vehicles and very difficult on foot.)	130–140
C	About 30 percent of trees blown down; remainder have some branches and leaves blown off (Fig. 6.24b). (Area passable to vehicles only after extensive clearing.)	90–100
D	Very few trees blown down; some leaves and branches blown off. (Area passable to vehicles.)	60–80

TABLE 6.29

GROUND SHOCK DAMAGE CRITERIA FOR MODERATELY DEEP UNDERGROUND STRUCTURES

Type of structure	Damage class	Distance from surface zero	Nature of damage
Relatively small, heavy, blast-resistant design (shelters).	A & B	1¼ crater radii.	Collapse or severe displacement.
	C	1¼ to 2 crater radii.	Shock damage to interior equipment.
	D	2 to 2½ crater radii.	Severance of brittle connections, slight cracking at structural discontinuities.
Relatively long, flexible (pipelines).	A	1½ crater radii.	Deformation and rupture.
	B	1½ to 2 crater radii.	Slight deformation with some rupture.
	C	2 to 3 crater radii.	Failure of connections.

may have one of the three forms indicated, according to the nature of the structure. The slope of the resistance-deflection curve in the elastic region is represented by K_1, whereas in the plastic region it is K_2. The maximum deflection to failure (or deflection prescribed for analysis) is indicated by X_m.

6.100 For reinforced-concrete or steel structures the dynamic resistance curve is derived from the static resistance-deflection curve by adding 20 percent to the values of the dynamic resistance at both X_e and X_m, i. e., at the points representing the yield and maximum deflections, respectively. For structures of masonry, wood, or metal, other than steel, the static resistance curve may be used. If the true static resistance curve is found to be of the form shown by the full curve in Fig. 6.100, it may be approximated by two (dashed) straight lines, the area under the "approximate curve" being equal to that under the "true curve."

Fundamental Period of Vibration

6.101 The fundamental period of vibration, T, of a structure is expressed by

$$T = 2\pi\sqrt{\frac{M_e}{K_1}}, \tag{6.101.1}$$

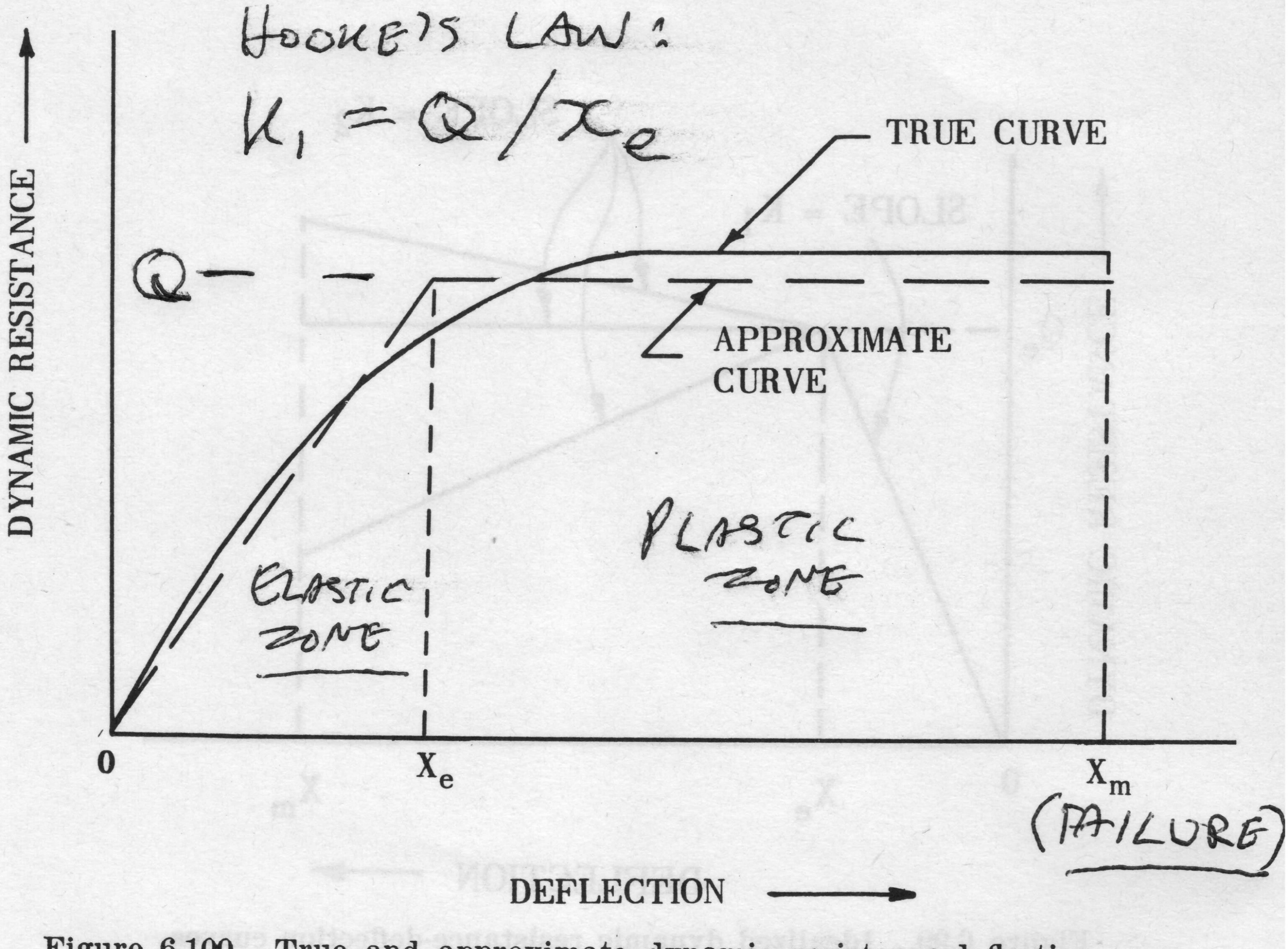


Figure 6.100. True and approximate dynamic resistance-deflection curve.

Peak Force-Deflection Relationship

6.105 With the necessary data secured in the manner described above, the solution of the structural response problem is obtained from the equation,

$$\frac{F}{Q_e}=\frac{T}{\pi t_1}(\sqrt{A}-\sqrt{D})+\frac{A-D}{2\frac{X_m}{X_e}\left(1+0.7\frac{T}{t_1}\right)}, \quad (6.105.1)$$

where

$$A=2\frac{X_m}{X_e}-1+\frac{K_2}{K_1}\left(\frac{X_m}{X_e}-1\right)^2$$

and

$$D=\left(\frac{2\pi I}{Q_e T}\right)^2 \text{ or } D=0 \text{ if } I \text{ is not computed.}$$

For convenience in the application of equation (6.105.1), the various symbols involved, all of which have been defined previously, are given below, together with their usual units:

F = peak force in pounds (see Fig. 6.102)
t_1 = duration of equivalent linear loading in seconds (see Fig. 6.102)
Q_e = yield resistance in pounds (see Fig. 6.99)
T = fundamental period of vibration in seconds (see equation (6.101.1))
I = initial impulse in pound-seconds (see Figs. 6.79, 6.87, and 6.102)
X_e = yield deflection in any units (see Fig. 6.99)
X_m = maximum (or prescribed) deflection in same units as X_e (see Fig. 6.99)
K_1 = slope of dynamic resistance-deflection curve in elastic region (see Fig. 6.99)
K_2 = slope of dynamic resistance-deflection curve in plastic region (see Fig. 6.99).

6.106 There are two general types of problems which may be solved with the aid of equation (6.105.1). If the load is prescribed, e. g., a given distance from an explosion of a specified yield, so that F may be regarded as known, the corresponding deflection, X_m, can be determined. Alternatively, if the maximum (or prescribed) deflection,

X_m, is given, the corresponding value of F can be calculated. In either case, the solution must be approached by a series of approximations.

6.107 If the load is specified, so that F and t_1 may both be regarded as known, a provisional value of X_m must first be estimated and then checked by means of equation (6.105.1). A new value is then tried, and so on, until agreement of the two sides is obtained. On the other hand, if a particular deflection, X_m, is decided upon to represent the degree of damage that can be tolerated or that is not to be exceeded, the calculation of F is somewhat more difficult, since t_1 is also unknown and this is dependent upon F. It is necessary, therefore, to guess a linear function for the variation of the force with time, so as to give t_1. With this, an approximate value of F is determined from equation (6.105.1), and a check of the guessed function is then made. This permits a new estimate of t_1, and the process is repeated until a satisfactory solution is obtained.

6.108 The use of the procedure just described can involve an error when the dynamic resistance curve shows the structure to be unstable, i. e., when K_2 is negative. The solution to a problem of determining the value of F to produce a deflection X_m may then imply that a greater force F is required for a smaller value of X_m. It is necessary, therefore, to check this possibility. For cases in which K_2 is negative, F is first determined for a certain X_m, say 2 feet, then F is redetermined for a somewhat smaller value of X_m, say 1.8 feet, which is greater than X_e but close to the original X_m. If the second value of F is greater than the first, the calculations must be continued to determine the maximum value of F, called F_m, which is associated with X_m. For any greater value of the deflection X_m, the force F_m is still required.

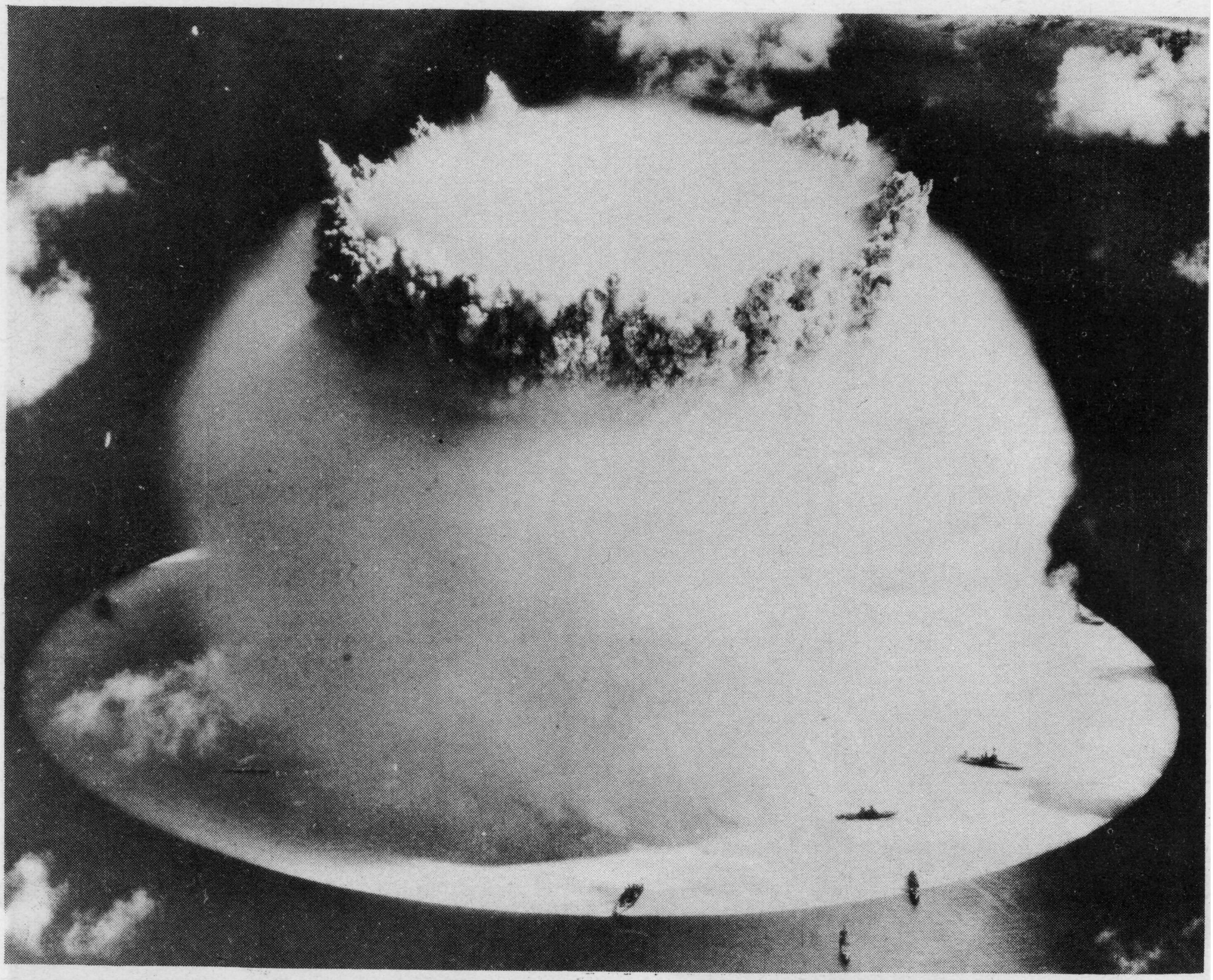


Figure 2.53a. The condensation cloud formed after a shallow underwater explosion. (The "slick," due to the shock wave, can be seen on the water surface.)

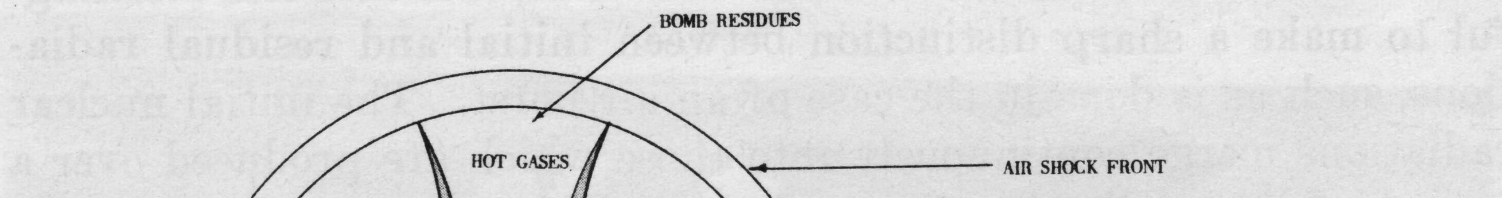


Figure 2.66a. Chronological development of a 100-kiloton shallow underwater burst: 2 seconds after detonation.

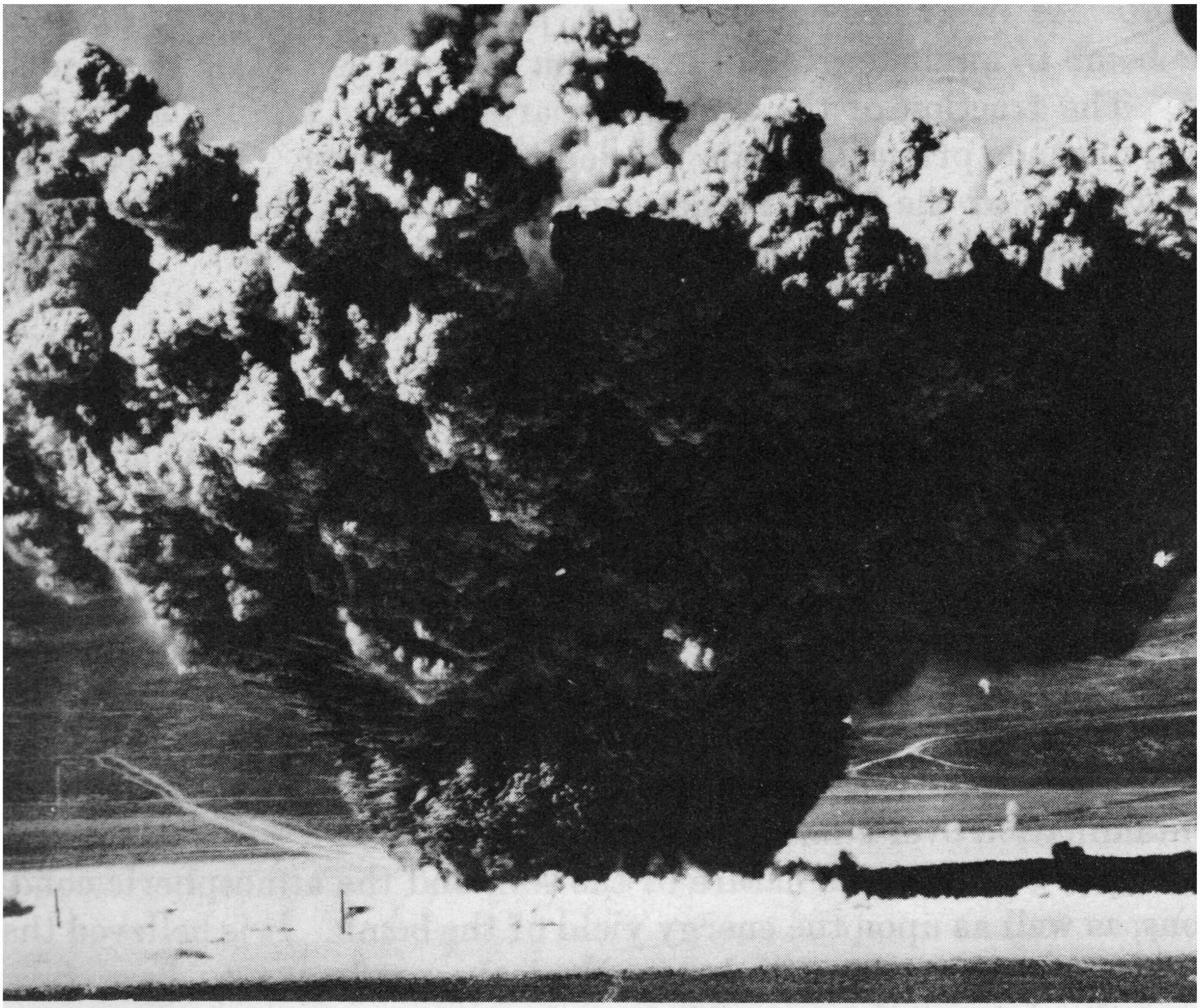


Figure 2.67. Shallow underground burst.

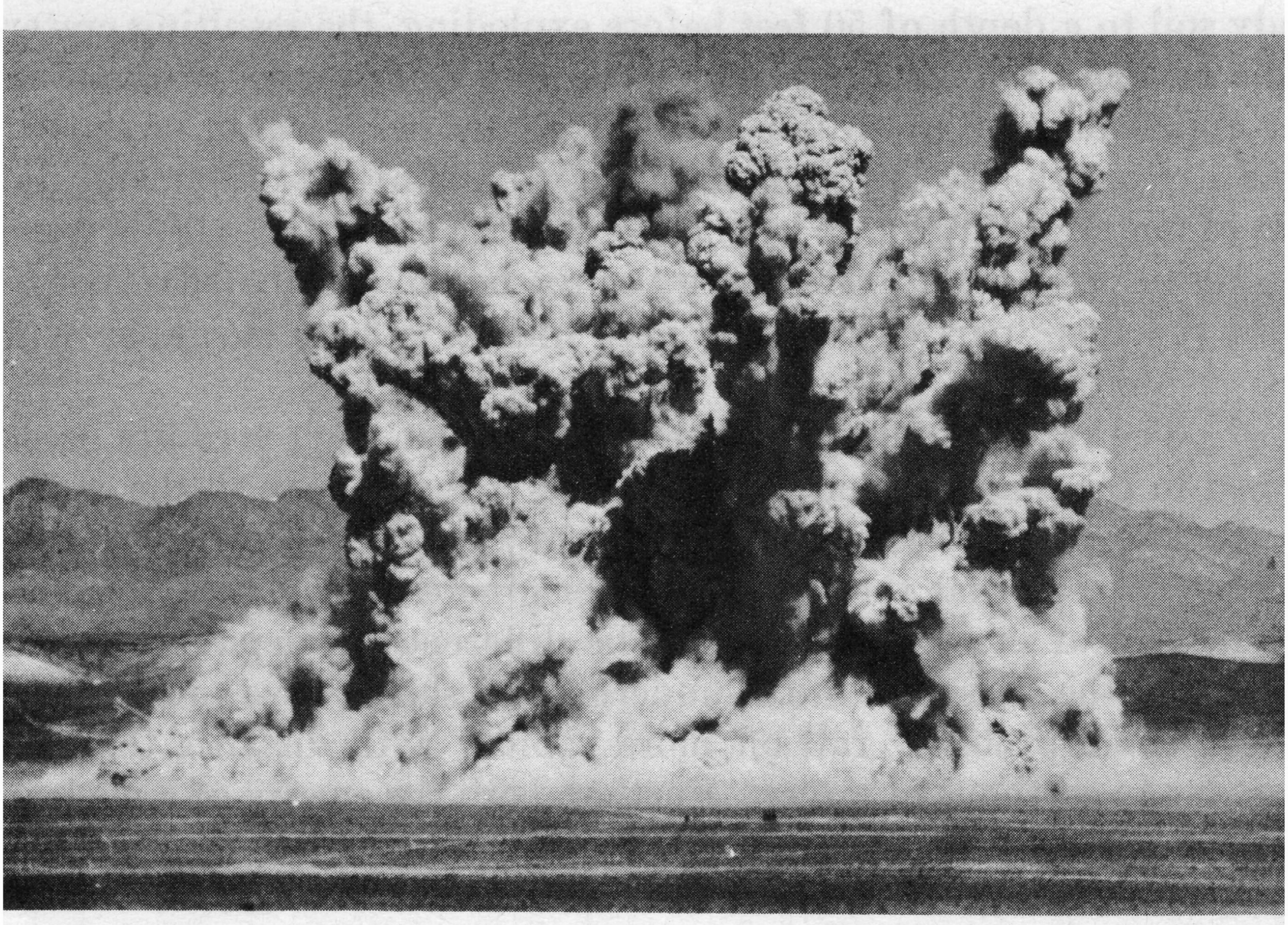


Figure 2.71. Base surge formation in underground burst.

Figure 5.37. Waves from the BAKER underwater explosion reaching the beach at Bikini, 11 miles from surface zero.

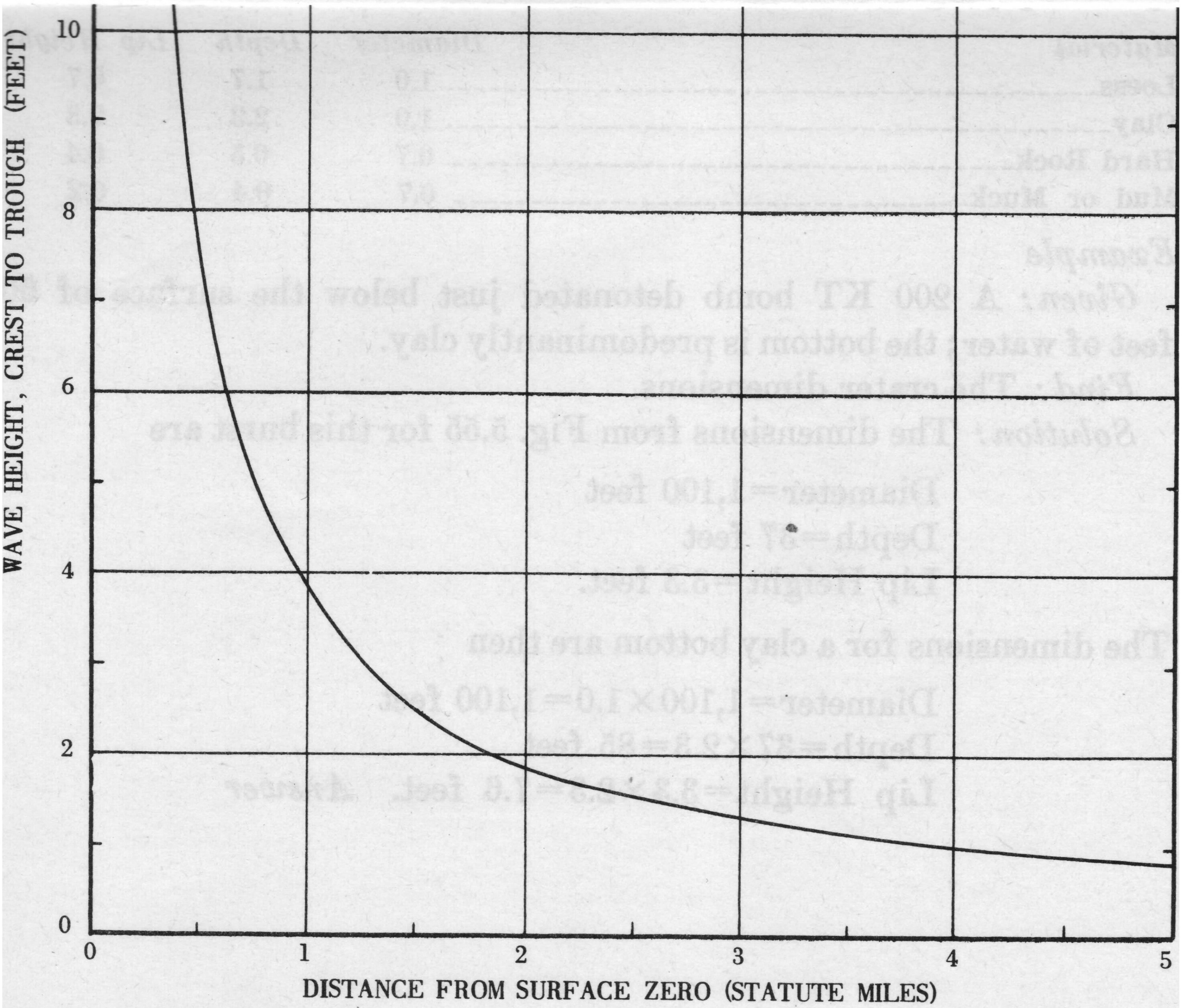


Figure 5.54. Maximum wave height (crest to trough) for a 1-kiloton explosion

TABLE 9.108

DIMENSIONS AND DOSE RATE OF CONTAMINATED WATER AFTER THE 20-KILOTON UNDERWATER EXPLOSION AT BIKINI

Time after explosion (hours)	Contaminated area (square miles)	Mean diameter (miles)	Maximum dose rate (roentgens per hour)
4	16.6	4.6	3.1
38	18.4	4.8	0.42
62	48.6	7.9	0.21
86	61.8	8.9	0.042
100	70.6	9.5	0.025
130	107	11.7	0.008
200	160	14.3	0.0004

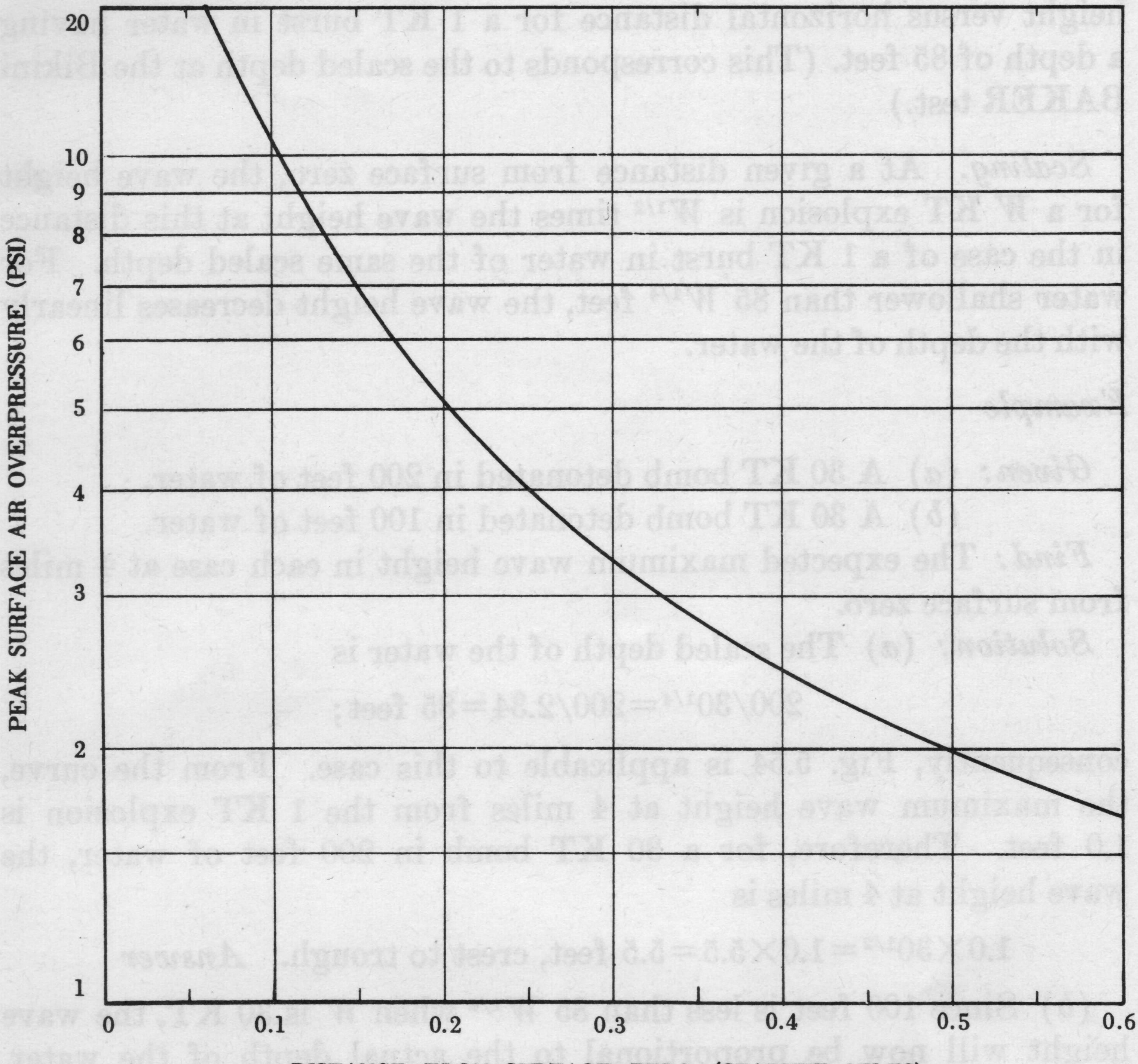


Figure 5.53. Peak air overpressure at surface for a 1-kiloton shallow underwater explosion.

Castle-Bravo, 15 mt Surface burst

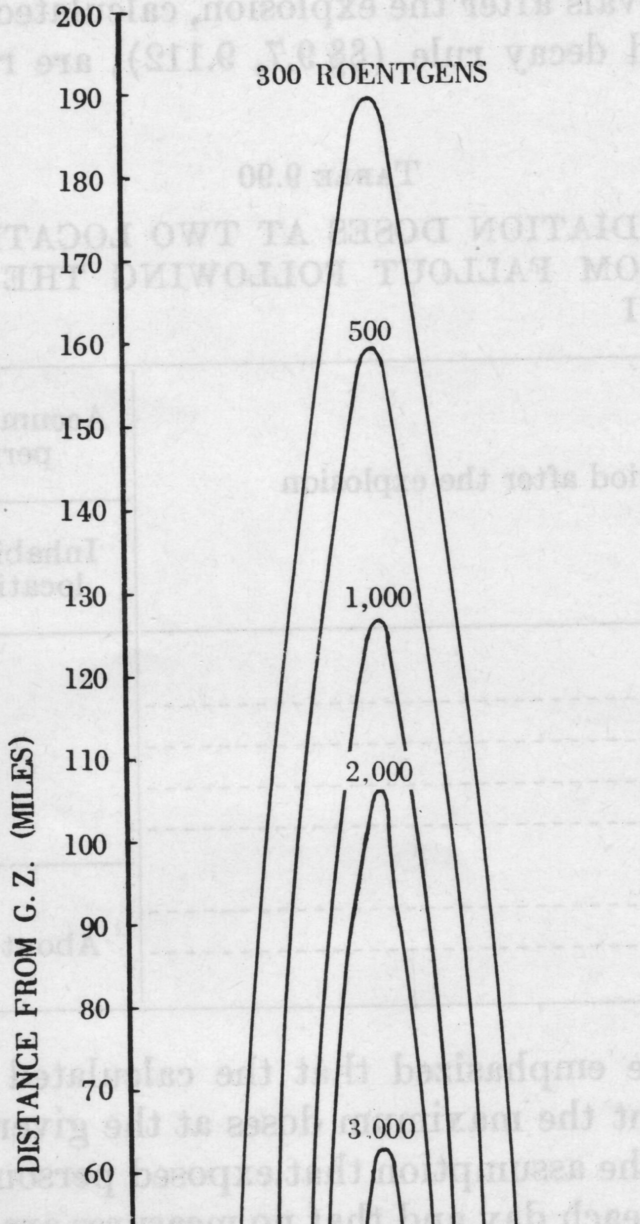


Figure 9.87. Idealized total (accumuiated) dose contours from fallout in first 36 hours after the high yield explosion at Bikini Atoll on March 1, 1954.

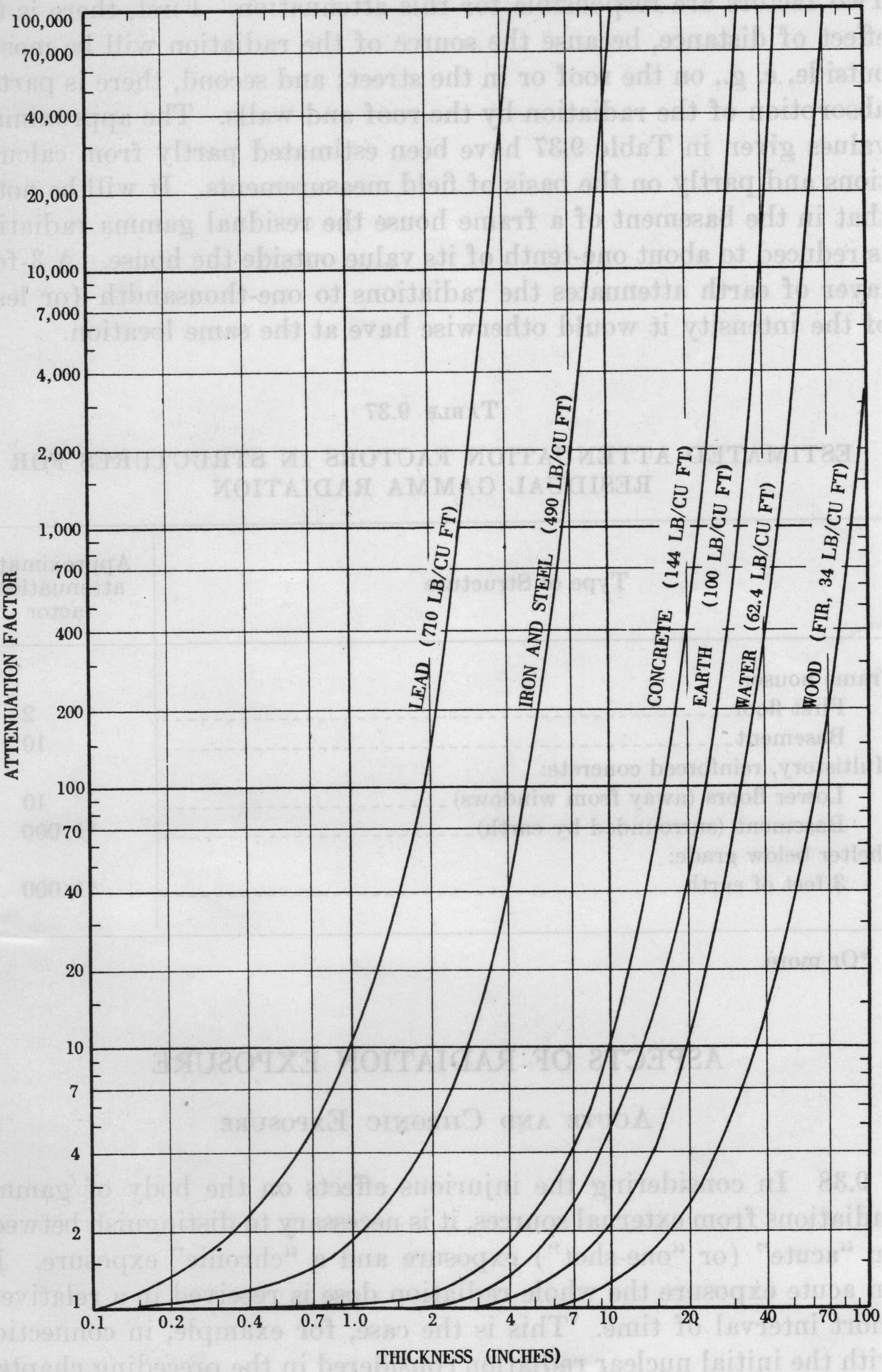


Figure 9.36. Attenuation of fission product radiation.

TABLE 9.37

ESTIMATED ATTENUATION FACTORS IN STRUCTURES FOR RESIDUAL GAMMA RADIATION

Type of Structure	Approximate attenuation factor
Frame house:	
First floor	2
Basement	10
Multistory, reinforced concrete:	
Lower floors (away from windows)	10
Basement (surrounded by earth)	*1, 000
Shelter below grade:	
3 feet of earth	*1, 000

*Or more.

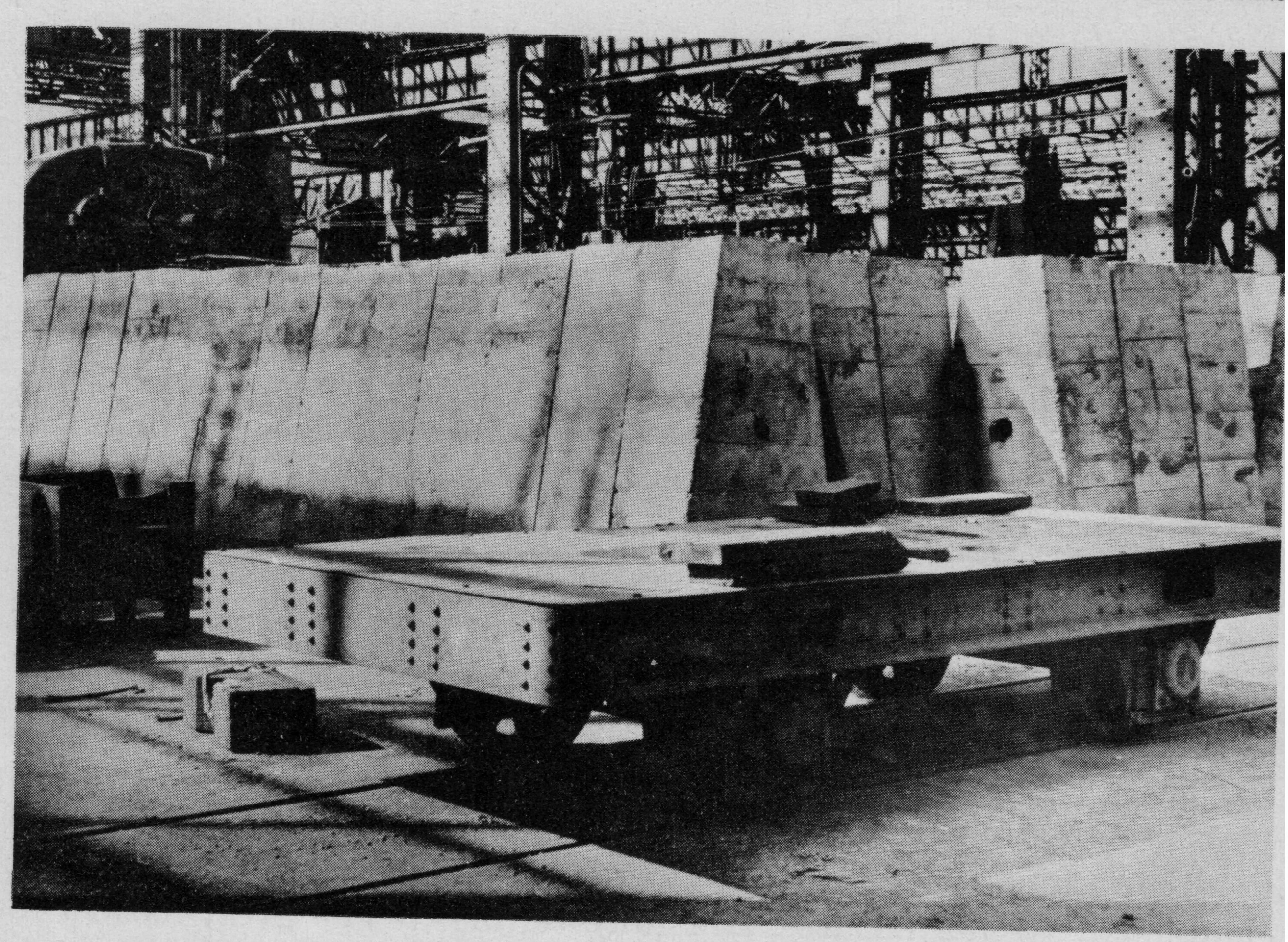


Figure 12.37a. Precast, reinforced-concrete blast walls (0.85 mile from ground zero at Nagasaki).

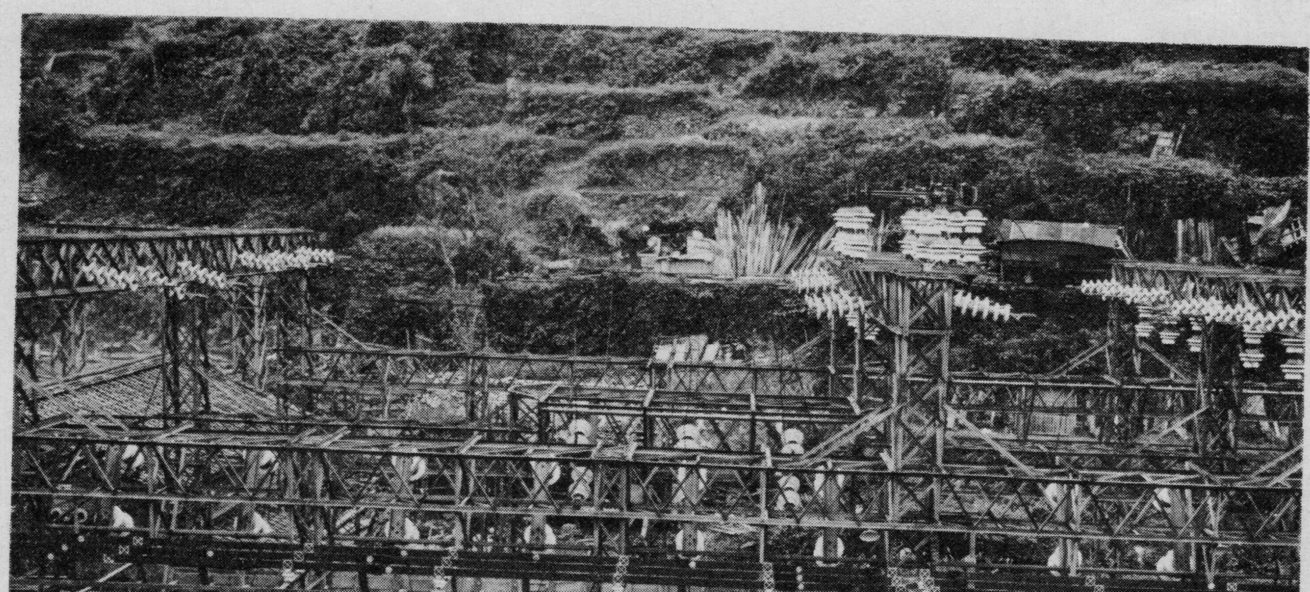


Figure 12.37b. Reinforced-concrete blast walls protecting transformers (1 mile from ground zero at Nagasaki).

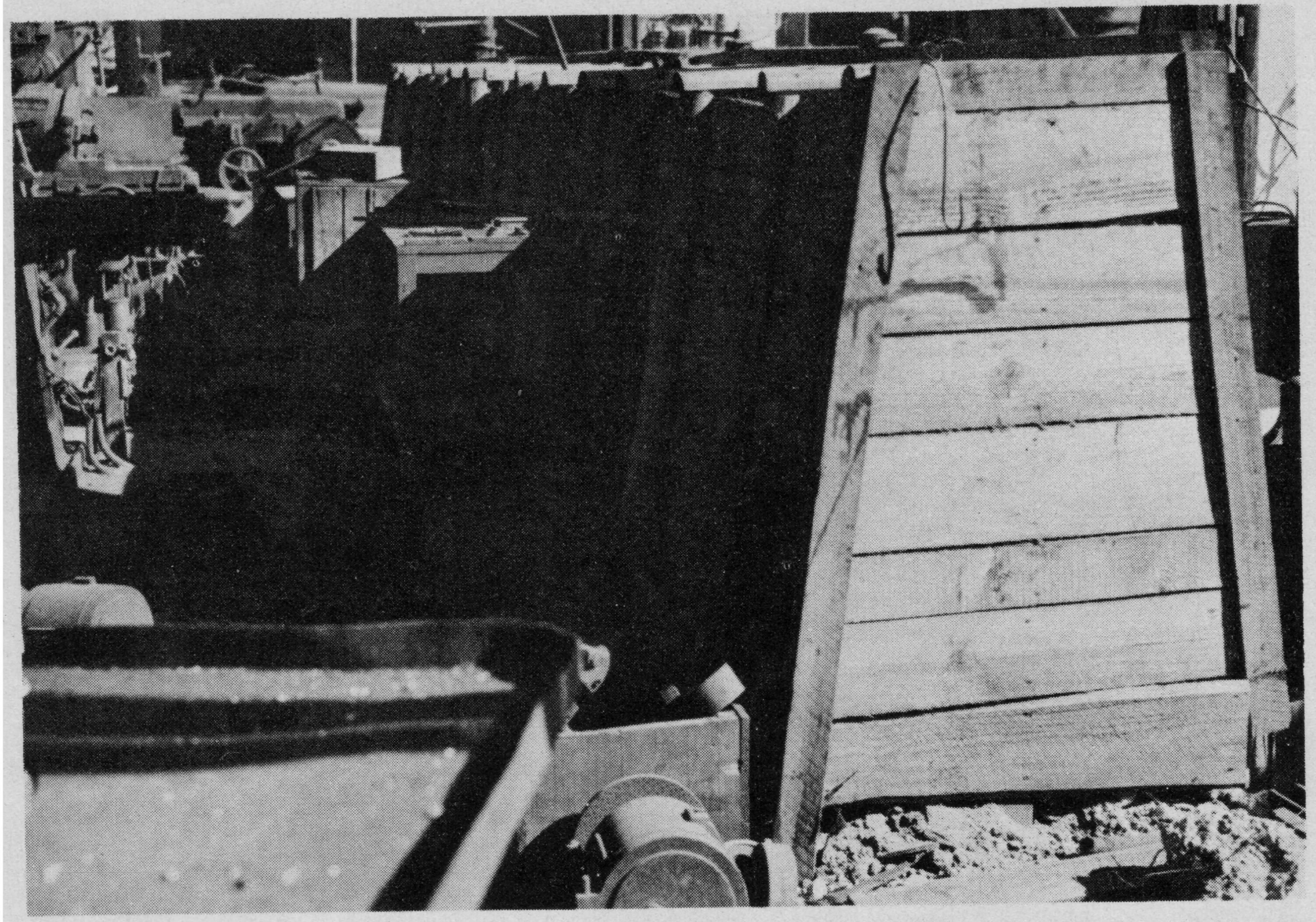


Figure 12.37c. Earth-filled, wooden blast walls protecting machinery (0.85 mile from ground zero at Nagasaki).

Protection by Trenches and Earth Revetments

12.38 Although they are not strictly structures, in the sense used above, attention should be called to the significant protection that can be afforded by trenches and earth revetments, especially to drag-sensitive targets. A shallow pit provides little shielding, but pits or trenches that are deeper than the target have been found to be very effective in reducing the magnitude of the drag forces impinging on any part of the target. In these circumstances, the lateral loading is greatly reduced and the damage caused is restricted mainly to that due to the crushing action of the blast wave.

12.39 The only types of shielding against drag forces which have been found to be satisfactory so far are those provided by fairly extensive earth mounds (or revetments) and deep trenches, since these are themselves relatively invulnerable to blast. Such protective trenches are not recommended for use in cities, however, because of the damage that would result from debris falling into them. Although sandbag mounds have proved satisfactory for protection against conventional high explosives and projectiles, they are inadequate against nuclear blast because they may become damaging missiles.

Figure 12.40a. Earth-moving equipment subjected to nuclear blast in open terrain (30 psi overpressure). TEAPOT-MET

Figure 12.40b. Earth-moving equipment subjected to nuclear blast in open terrain (30 psi overpressure). TEAPOT-MET

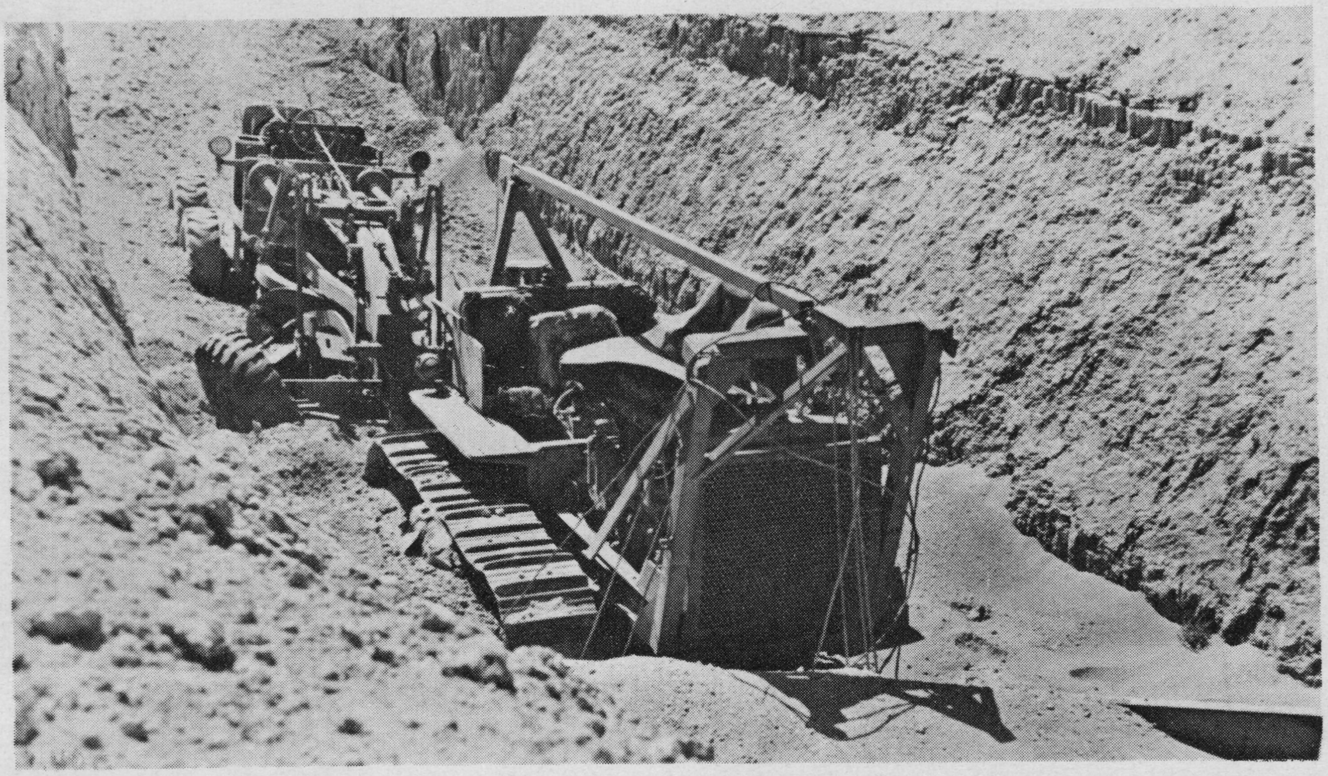


Figure 12.40c. Earth-moving equipment protected in deep trench at right angles to blast wave motion (30 psi overpressure). MET 1952

12.40 The destruction caused by a nuclear explosion to two pieces of earth-moving equipment, which are largely drag-sensitive, is shown in Figs. 12.40a and b. Two similar pieces of equipment located in a deep trench, at the same distance from the explosion, are seen in Fig. 12.40c to have been essentially unharmed. It is important to mention that the main direction of the trench was at right angles to the motion of the blast wave. If the wave had been traveling in the same direction as the trench, the equipment would probably have been severely damaged. Consequently, in order to provide protection from drag forces, the orientation of the trench or earth revetment, with respect to the expected direction of the explosion, is of great importance.

Fire Protection

12.41 It was noted in Chapter VII that fires following a nuclear explosion may be started by thermal radiation and by secondary effects, such as overturning stoves and furnaces, rupture of gas pipes, and electrical short circuits. Fire-resistive construction and avoidance of fabrics and other light materials of inflammable character are essential in reducing fire damage. As shown by the tests described in § 7.82, a well-maintained house, with a yard free from inflammable rubbish, was less easily ignited by thermal radiation than a house that has not had adequate care.

12.42 The methods of fire-resistive design and of city planning are well known and the subject need not be treated here. A special requirement is the reduction of the chances of ignition due to thermal radiation by the avoidance of trash piles and other finely divided fuel as well as combustible, especially dark colored, materials that might be exposed at windows or other openings. It has been recommended, in this connection, that all such openings be shielded against thermal radiation from all directions. The simple device of whitewashing windows will greatly reduce the transmission of thermal radiation and so decrease the probability of fires starting in the interior of the building. Other practical possibilities are the use of metal venetian blinds, reflective coatings on the window glass, and nonflammable interior pull curtains.

12.43 To judge from the experience in Japan, where the distortion by heat of exposed structural frames was considerable, it would appear desirable that steel columns and other steel members be protected from fire, especially where the contents of the building are flammable or where the building is located adjacent to flammable structures. Further, narrow firebreaks in Japan were found to be of little value. It is vital, therefore, that such firebreaks as may be provided in city planning or by demolition must be adequate for a major conflagration. A minimum width of 100 feet has been suggested.

12.44 One of the most important lessons learned from the nuclear bomb attacks on Japan is the necessity for the provision of an adequate water supply for the control of fires. In Nagasaki, the water pressure was 30 pounds per square inch at the time of the explosion, but chiefly because of numerous breaks in house service lines it soon dropped to 10 pounds per square inch. On the day following the explosion the water pressure was almost zero. This drop in the pressure contributed greatly to the extensive damage caused by fire. The experience in Hiroshima was quite similar.

SHELTERS FOR PERSONNEL

Introduction

12.45 Ideally, a shelter for personnel might be required to provide protection against air blast, ground shock, thermal radiation, initial nuclear radiation (neutrons and gamma rays), and residual nuclear radiation from fallout (external and internal sources). Such an ideal shelter is, however, virtually impossible to attain, in view of the uncertainties mentioned in § 12.2. Thus, shelter design, like that of

UNDERGROUND PERSONNEL SHELTER

12.53 Where essential industrial, civic, or military activities must be maintained before, during, and after a nuclear attack, it might be desirable to have a group shelter which could be occupied continuously, although not necessarily by the same individuals. A shelter of this kind would be of the closed type and would have to be provided with a suitable ventilating system. As a result of various tests, it has been found that in "open" shelters, i. e., in shelters which are open to the entry of the blast, the peak overpressure of the blast wave is not very different from that outside. Some reduction can be achieved by suitable design of the entrance and by the use of baffles, but the general impression is that, in strategic locations, where high overpressures may be expected, open group shelters would not be adequate.

12.54 The general features of a closed, underground personnel shelter, that can accommodate some 30 individuals at a time, but can be extended to hold more, are shown in Fig. 12.54. The design is based on experience gained at various nuclear tests in which shelters of this type have withstood peak overpressures of about 100 pounds per square inch. It was also found, as expected, to produce considerable attenuation of both gamma rays and neutrons.[3]

12.55 The main shelter chamber has reinforced-concrete walls 15 inches thick; the floor slab has a thickness of 18 inches and that of the roof is 21 inches. The chamber is covered with packed earth to a depth of at least 5 feet. The entrance is by concrete steps, in two sections at right angles. Instead of extending in the direction shown in the figure, the entranceway may be turned through 180°, so as to make the whole lay-out more compact. The stairway at the ground level is closed by means of an 8-inch thick horizontal door made of structural steel and reinforced concrete. The door has four wheels and is track mounted. It is so designed that as it rolls closed it seats itself on steel bed plates on each side of the stairwell, so that the blast load is removed from the wheels and axles. A heavy jack is mounted on the underside of the ceiling of the stairwell, so that the door can be forced open in case there is an accumulation of debris in the well behind the door.

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[3] The shelter described here was conceived and planned by the Federal Civil Defense Administration, with the assistance of the Army Ballistics Research Laboratory, the Army Chemical Center, and the Armed Forces Special Weapons Project. The structural design was by Ammann and Whitney, Consulting Engineers, under contract to the Federal Civil Defense Administration.

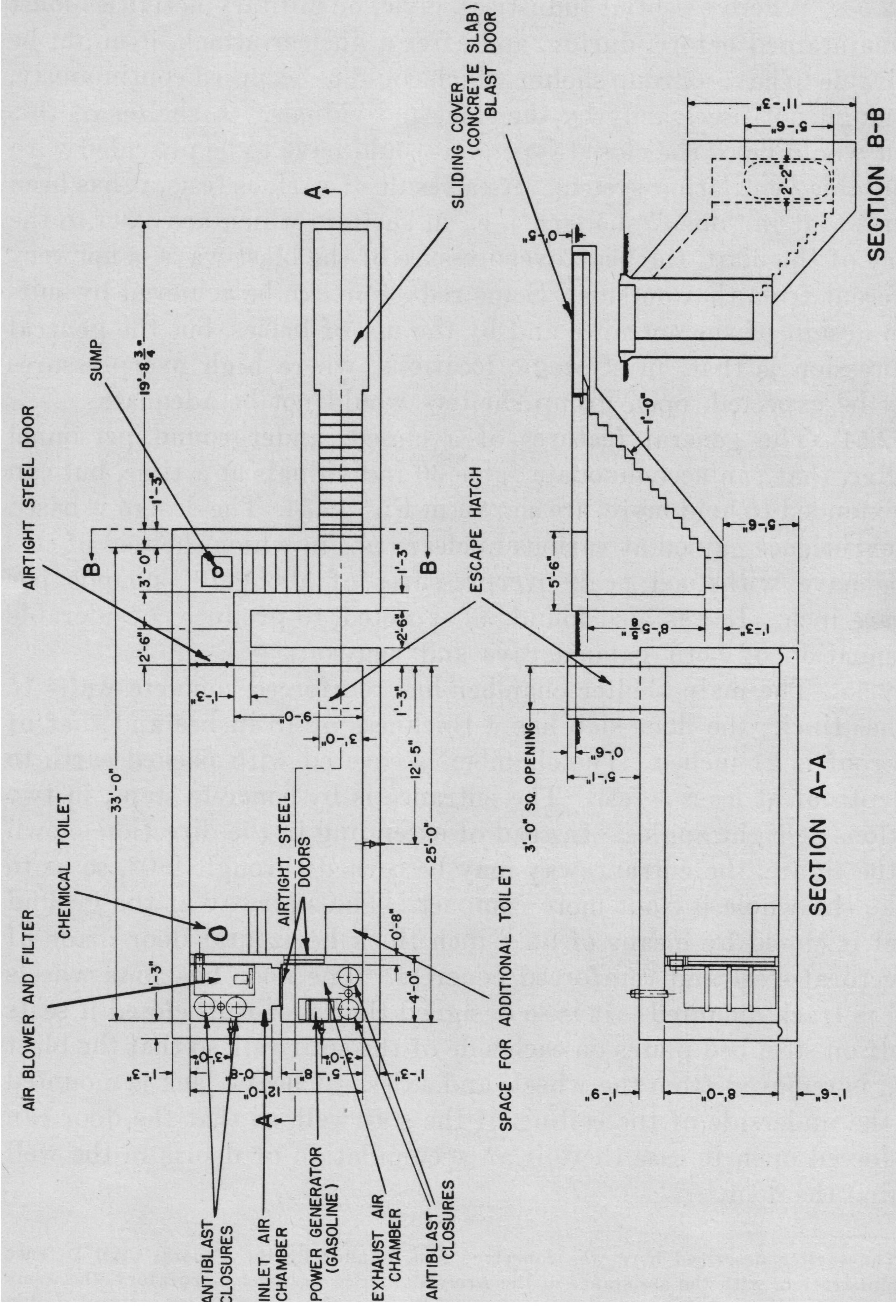


Figure 12.54. Sectional plan and section of underground personnel shelter.

12.60 In the event of a surprise attack, when there is no opportunity to take shelter, immediate action could mean the difference between life and death. The first indication of an unexpected nuclear explosion would be a sudden increase of the general illumination. It would then be imperative to avoid the instinctive tendency to look at the source of light, but rather to do everything possible to cover all exposed parts of the body. A person inside a building should immediately fall prone and crawl behind or beneath a table or desk. This will provide a partial shield against splintered glass and other flying missiles. No attempt should be made to get up until the blast wave has passed, as indicated possibly by the breaking of glass, cracking of plaster, and other signs of destruction. The sound of the explosion also signifies the arrival of the blast wave.

12.61 A person caught in the open by the sudden brightness due to a nuclear explosion, should drop to the ground while curling up to shade the bare arms, hands, neck, and face with the clothed body. Although this action may have little effect against gamma rays and neutrons, it might possibly help in reducing flash burns due to thermal radiation. The degree of protection provided will vary with the energy yield of the explosion. As stated in § 7.53, it is only with high-yield weapons that evasive action against thermal radiation is likely to be feasible. Nevertheless, there is nothing to be lost, and perhaps much to be gained, by taking such action. The curled-up position should be held until the blast wave has passed.

12.62 If shelter of some kind, no matter how minor, e. g., in a doorway, behind a tree, or in a ditch, or trench can be reached within a second, it might be possible to avoid a significant part of the initial nuclear radiation, as well as the thermal radiation. But shielding from nuclear radiation requires a considerable thickness of material and this may not be available in the open. By dropping to the ground, some advantage may be secured from the shielding provided by the terrain and surrounding objects. However, since the nuclear radiation continues to reach the earth from the atomic cloud as it rises, the protection will be only partial. Further, as a result of scattering, the radiations will come from all directions.

PROTECTION FROM FALLOUT

12.86 In a city, decontamination could be carried out by hosing the roofs of buildings and the streets with strong streams of water. The radioactive material would thus be transferred to the storm sewers, where it would represent only a minor hazard. As an alternative to hosing, the dose rate inside a building could also be reduced by covering the ground surrounding the building with uncontaminated earth or by removing the top layer of the ground to a distance with a bulldozer.

12.87 It is important to note, in connection with removal of contaminated earth, for the purpose just described or to provide a means of transit, that the gamma rays from fission products can travel considerable distances through air. For example, at 3 feet above the ground, roughly 50 percent of the dose rate received in the center of a large, flat, uniformly contaminated area comes from distances greater than 25 feet away, and about 25 percent from distances more than 50 feet away. Thus, complete removal of the contaminated surface from a circle 50 feet in radius would reduce the dose rate in the center to about one-fourth of its original value. However, if the contaminated earth were not completely removed, but just pushed to the outside of the circle, the dose rate would be considerably larger than one-fourth the initial value.

12.88 It is apparent, therefore, that if transit facilities are to be provided across open country which is contaminated over a large area, bulldozing the top few inches of contaminated soil to the sides will be satisfactory only if a wide strip is cleared. Thus, if the strip is 250 feet in width, the radiation dose rate in the middle will be reduced to one-tenth of the value before clearing. A similar result may be achieved by scraping off the top layer of soil and burying it under fresh soil. Something like a foot of earth would be required to decrease the dose rate by a factor of ten.

12.89 Badly contaminated clothing, as well as rugs, curtains, and upholstered furniture, would have to be discarded and buried or stored in an isolated location. When the radioactivity has decayed to a sufficient extent, or if the initial contamination is not too serious, laundering may be effective in reducing the activity of clothing and fabrics, to permit their recovery. Thorough vacuum cleaning of furniture might be adequate in some cases, but an instrument check would be necessary before further use.

PAMPHLET
No. 39-1

HEADQUARTERS,
DEPARTMENT OF THE ARMY
WASHINGTON 25, D.C., *20 May 1959*

NUCLEAR WEAPONS EMPLOYMENT

***This pamphlet supersedes DA Pam 39-1, 12 June 1956, including C 1, 31 May 1957.**

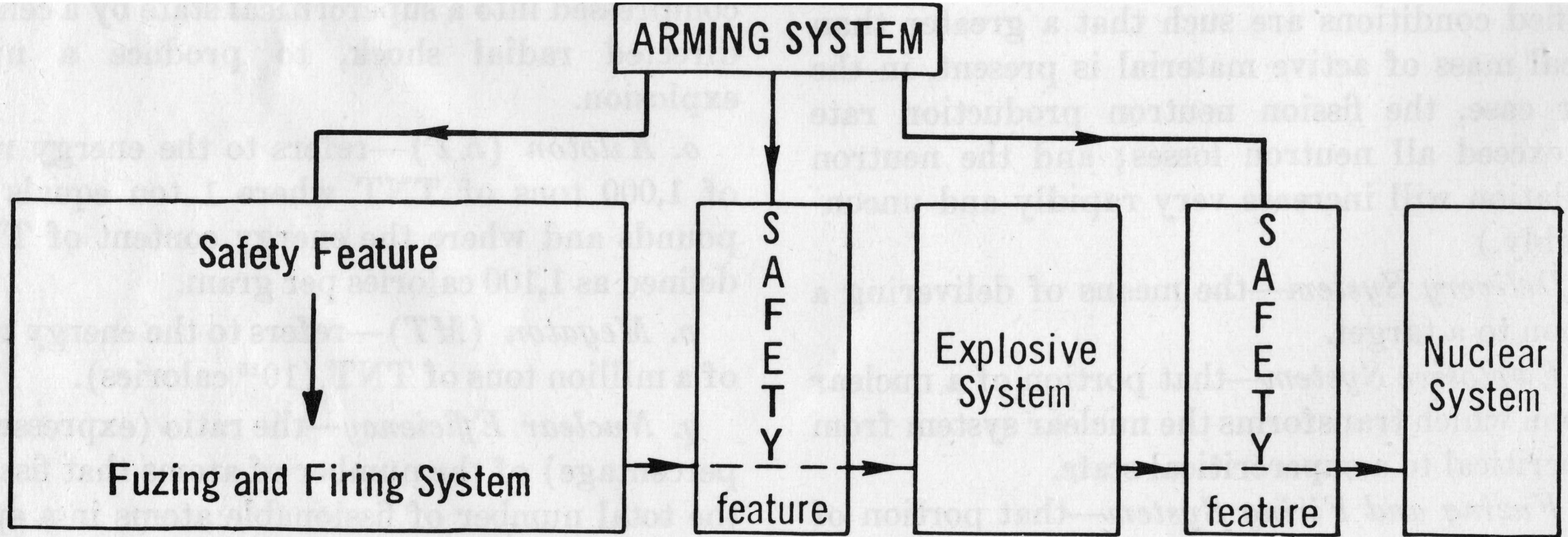


Figure 1.2. Relationship of arming, and the fuzing and firing, explosive, and nuclear systems of a nuclear weapon.

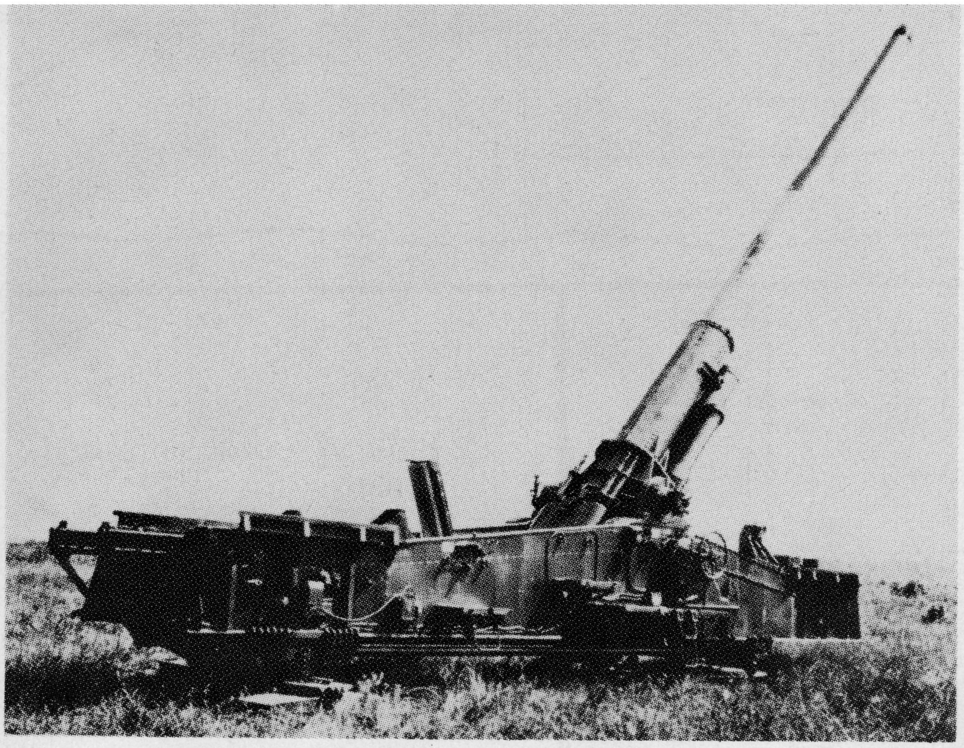


Figure 1.25a. 280-mm gun.

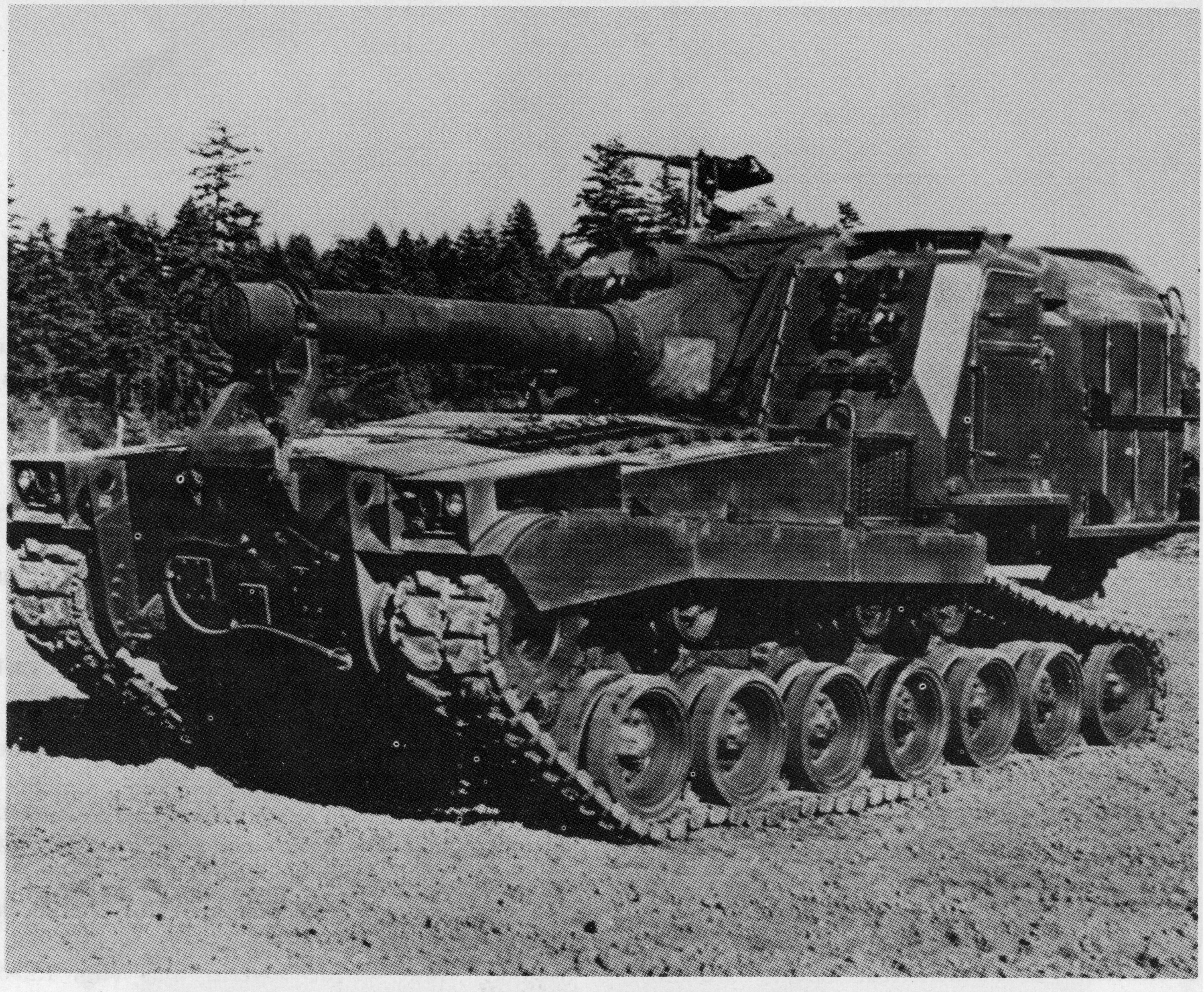
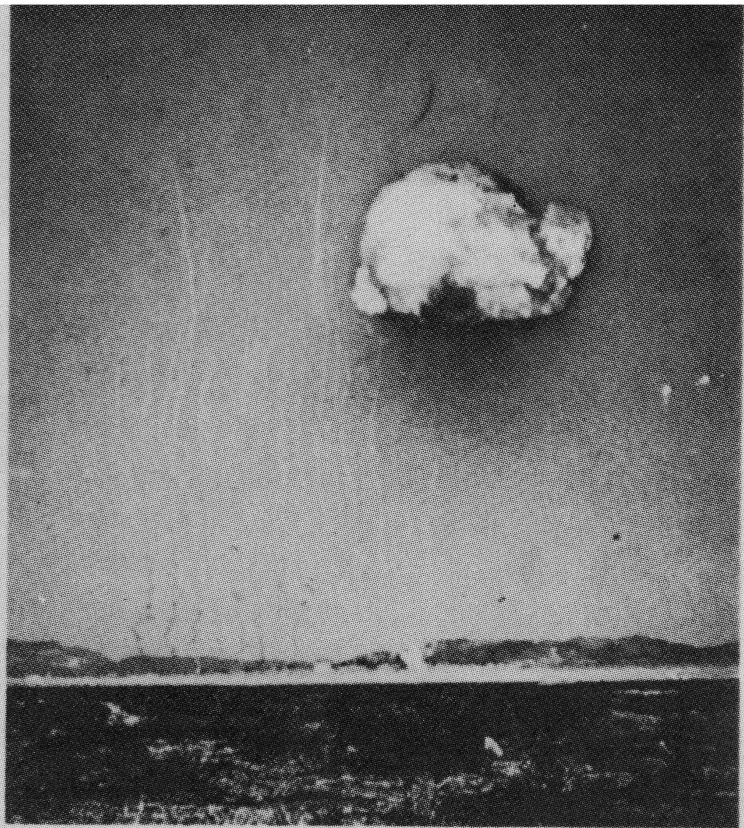


Figure 1.25b. 8-in. howitzer, self-propelled.

Figure 1.25d. **HONEST JOHN.**



HIGH

LOW

Figure 2.8 — High and low air bursts

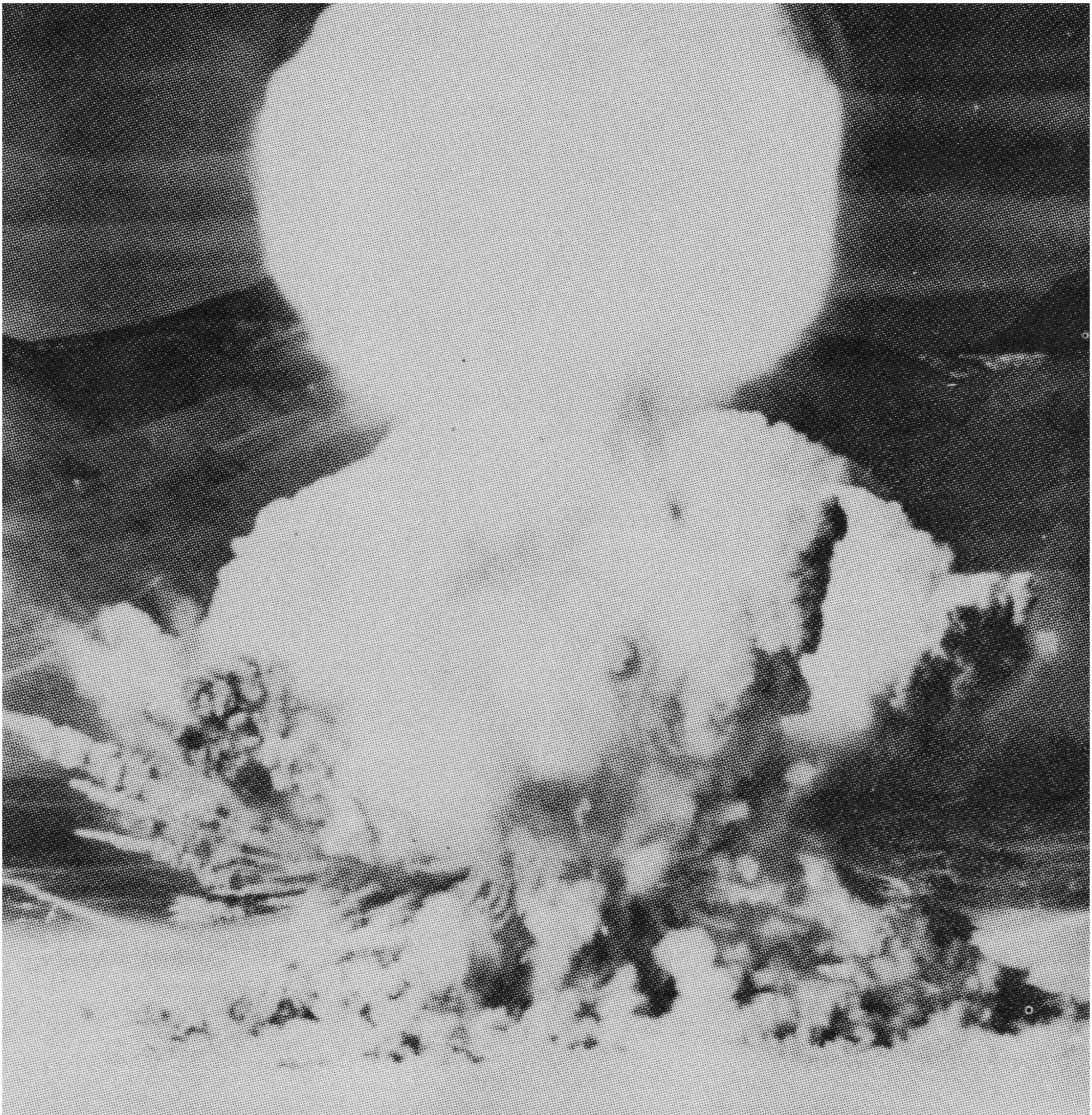
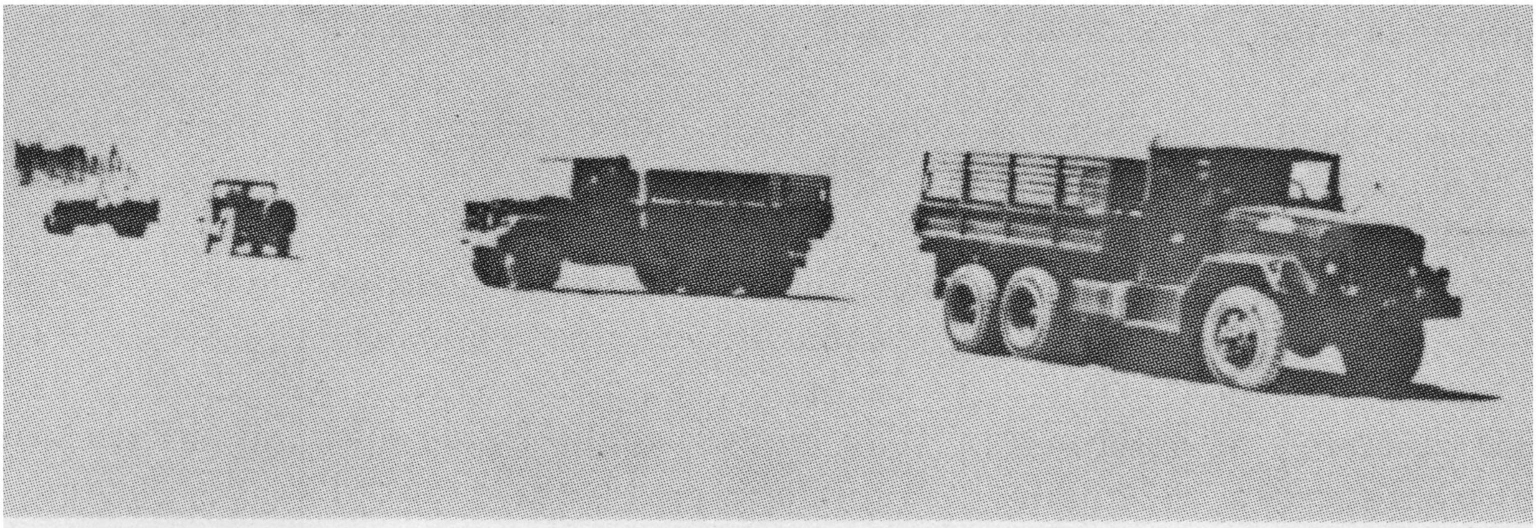


Figure 2.4. Surface burst.



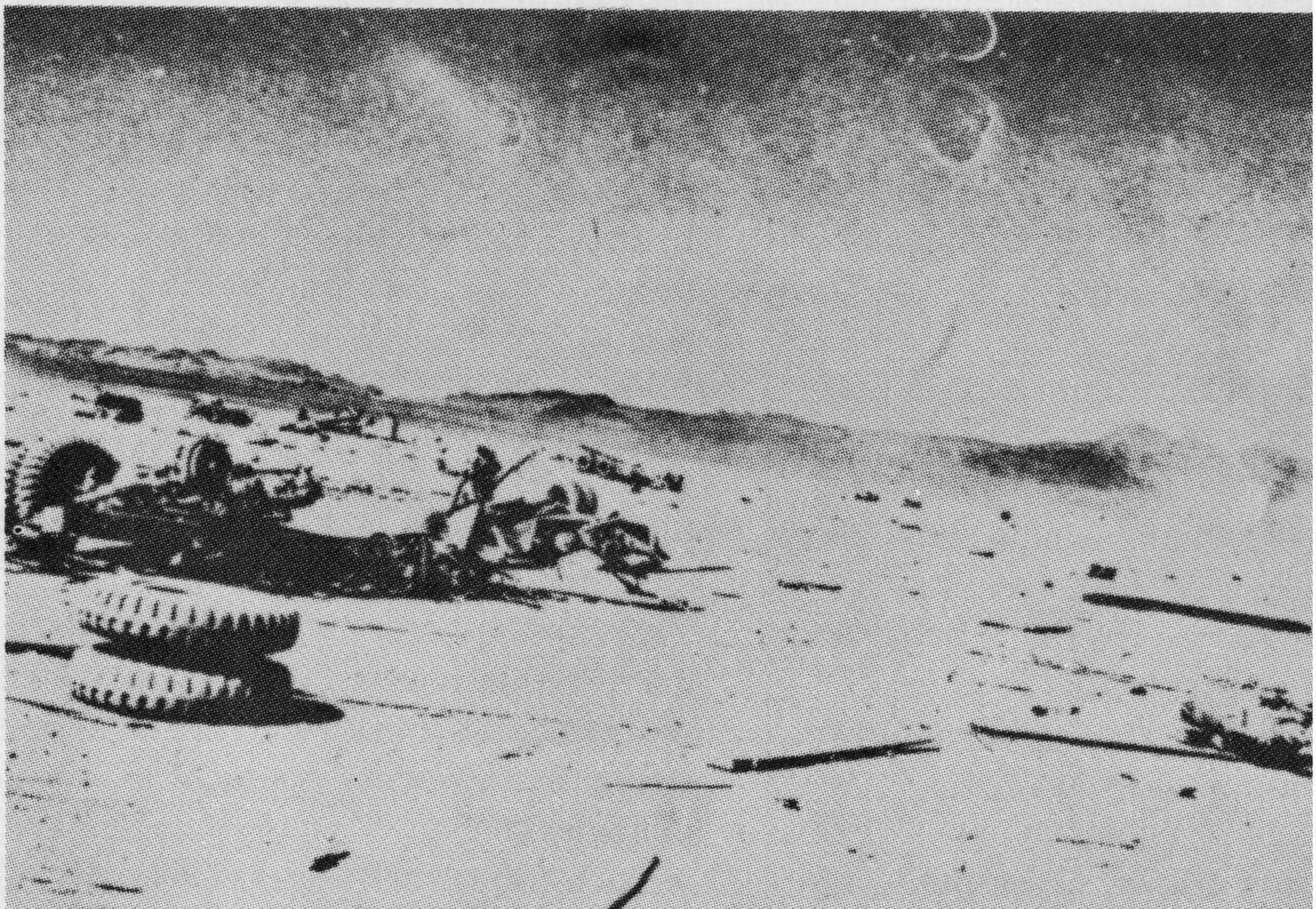


Figure 2.15b. Drag type target.

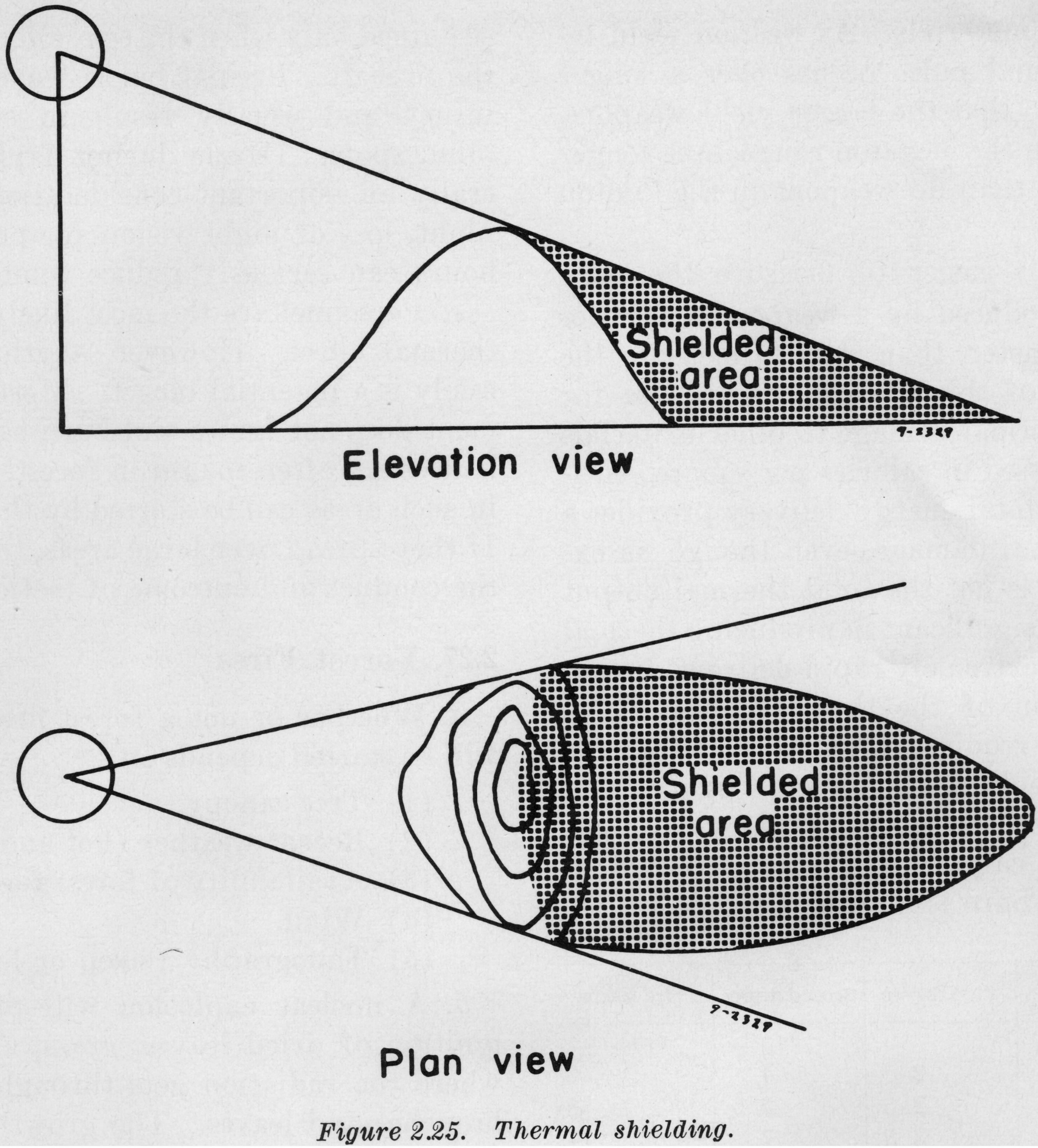


Figure 2.25. Thermal shielding.

Acute dose (roentgens) [1]	Probable effect
0 to 50	No obvious effect except possibly minor blood changes.
80 to 120	Vomiting and nausea for about 1 day in 5 to 10 percent of exposed personnel. Fatigue but no serious disability.
130 to 170	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 25 percent of personnel. No deaths anticipated.
180 to 220	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 50 percent of personnel. No deaths anticipated.
270 to 330	Vomiting and nausea in nearly all personnel on first day, followed by other symptoms of radiation sickness. About 20 percent deaths within 2 to 6 weeks after exposure; survivors convalescent for 3 months.
400 to 500	Vomiting and nausea in all personnel on first day, followed by other symptoms of radiation sickness. About 50 percent deaths within 1 month; survivors convalescent for about 6 months.
550 to 750	Vomiting and nausea in all personnel within 4 hours from exposure, followed by other symptoms of radiation sickness. Up to 100 percent deaths; few survivors convalescent for about 6 months.
1,000	Vomiting and nausea in all personnel within 1 to 2 hours. Probably no survivors.
5,000	Incapacitation almost immediately. All personnel will be fatalities within 1 week.

[1] And/or rem in the case of neutrons.

Figure 2.39. Probable effects of accute radiation doses.

2.40. Characteristics of Acute Radiation Injury

a. Very large doses of whole body radiation, 5,000 roentgens (rem) or more, result in very rapid injury to the central nervous system. The symptoms are—

(1) Lack of muscular coordination.
(2) Difficulty in breathing.
(3) Intermittent stupor.

There is almost immediate incapacitation, and death is certain within a few hours to a week.

b. Doses of about 700 to 1,000 roentgens (or rem) result in severe injury to the gastro-intestinal system. The symptoms are—

(1) Nausea and vomiting within one to two hours (the larger the dose, the sooner symptoms appear).
(2) Prostration, diarrhea, lack of appetite, and fever.
(3) Internal bleeding, infection, soreness of throat, and loss of hair. The sooner these symptoms develop, the sooner death is likely to result. Although there is no pain during the first few days, patients experience feelings of discomfort, depression, and body fatigue. In some cases the initial severe sickness disappears and is followed by a so-called *latent period*, during which the patient appears to be free of symptoms. This period, when it occurs, is followed by severe sickness, delirium or coma, and death within one to two weeks.

ENTRY TIME—STAY TIME—TOTAL DOSE FALLOUT RADIATION

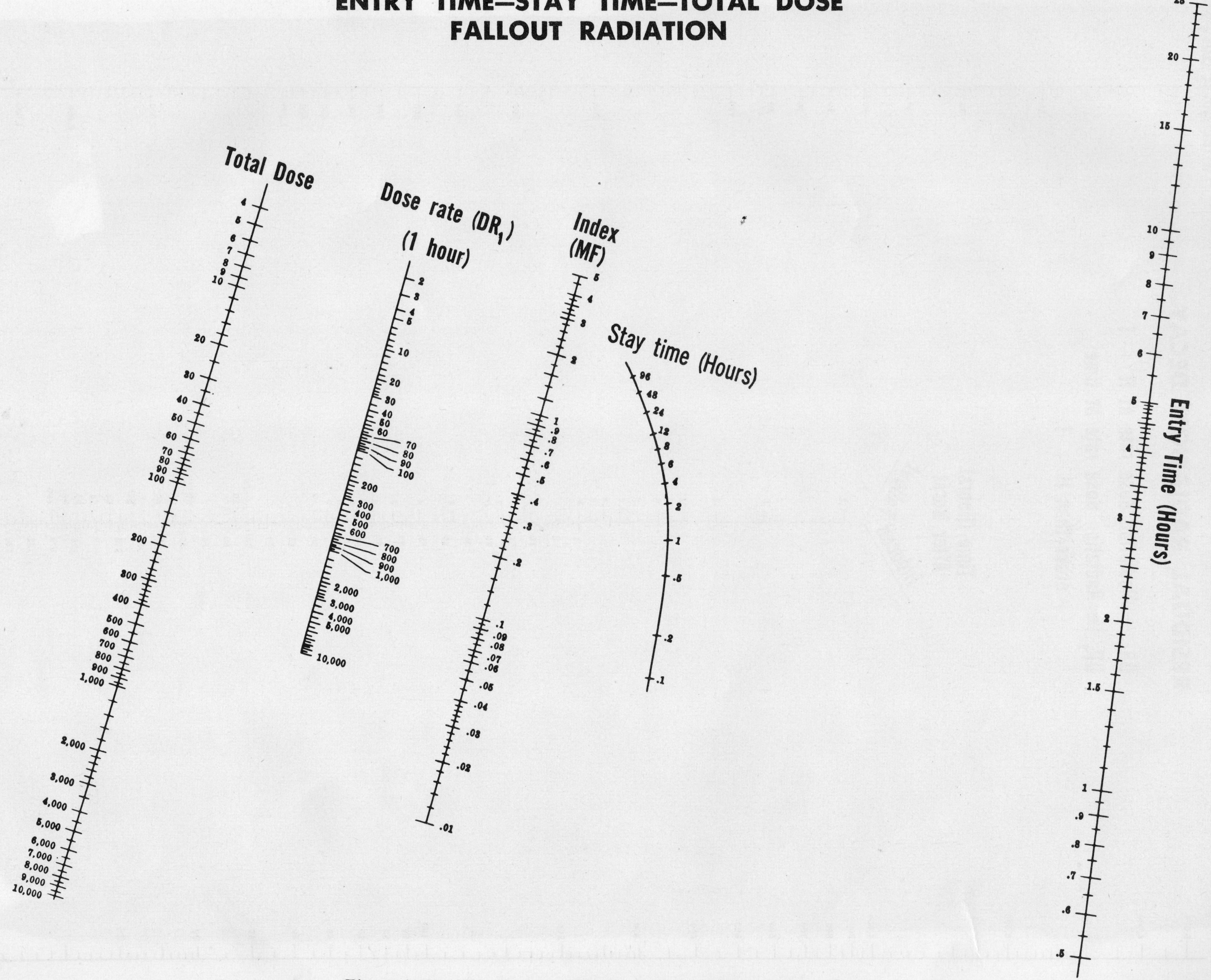


Figure 10.11. Nomogram 4, Determination of total dose (fallout).

Time for noneffectiveness	Total dose	
	Initial (rem)	Residual (r)
Immediate	5,000	5,000
1 hour	1,000	1,000
2 hours	750	600
4 hours	500	300
24 hours	300	150

Figure 10.12. Nuclear radiation criteria for casualties.

Environment	Initial		Residual
	Neutrons	Gamma	
Armored carrier	0.8	0.6	0.25
Urban area (in open)	1.0	0.5	0.8
Foxholes	0.25	0.1	0.2
Frame house			
First floor	1.0	0.7	0.5
Basement	0.7	0.4	0.1
Multistory buildings			
Top floor	1.0	0.7	0.5
Lower floors	0.7	0.4	0.1
Basement	0.5	0.25	0.01
Rough terrain	1.0	1.0	0.8
Shelter, closed (3 ft earth cover)	0.1	0.04	0.001
Tanks			
Light	0.7	0.33	0.15
Medium or heavy	0.5	0.15	0.05
Trucks			
¼-ton	1.0	1.0	0.8
2½-ton	1.0	0.9	0.6
Woods	1.0	1.0	0.8

Figure 10.13. Transmission factors for nuclear radiation—(ratio of protected to unprotected dose or dose rate).

PORTABLE DOSE RATEMETER

(RADIAC SURVEY METER No. 1)

1038A & 1155A

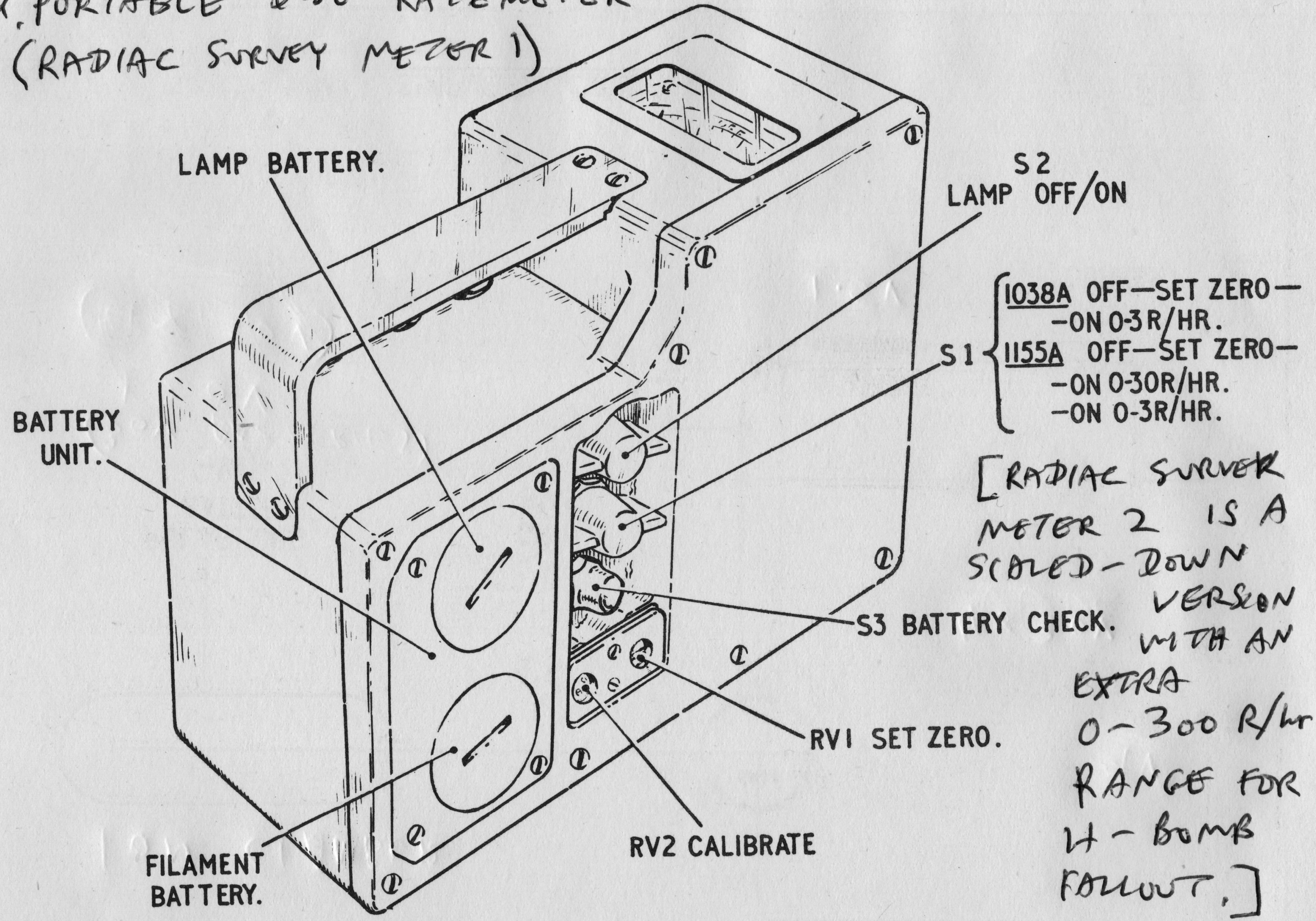
$\underbrace{\hphantom{1038A}}$ 0 – 3 R/hr (ONE RANGE ONLY)

$\underbrace{\hphantom{1155A}}$ 0 – 3 R/hr & 0 – 30 R/hr (TWO RANGES)

INSTRUCTION MANUAL ISSUE. 1.

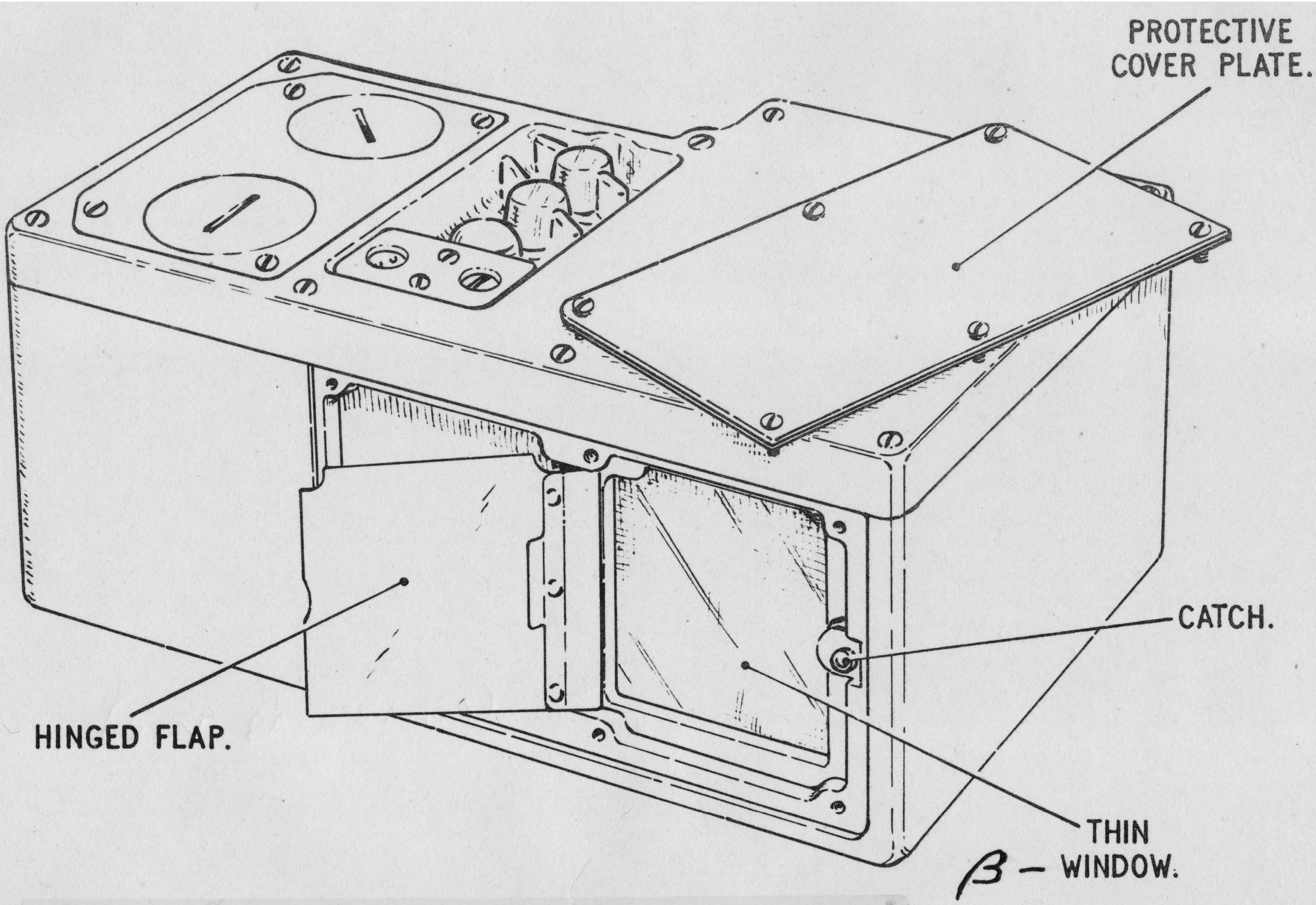
Published by:
Specifications and Manuals Section, A.E.R.E. Harwell from whom extra copies may be obtained if desired.

UK. PORTABLE DOSE RATEMETER
1 (RADIAC SURVEY METER 1)



[RADIAC SURVEY METER 2 IS A SCALED-DOWN VERSION WITH AN ~~EXTRA~~ 0-300 R/hr RANGE FOR H-BOMB FALLOUT.]

3.75" x 9" x 6" HIGH, 9 lbs.



$$I = \frac{V.R.}{10.8.} \text{ micro-micro amps.}$$

where V = ionization chamber volume (c.c.)
R = Dose Rate (Rontgen/hr).

In the portable dose rate meter type 1038A, the ionization chamber volume is about 310 cc, and the full scale dose rate is 3R/hr